RESEARCH AT USAFA

2013

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RESEARCH AT USAFA 2013

The mission of the United States Air Force Academy is to educate, train, and inspire men and women to become officers of character motivated to lead the United States Air Force in service to our nation. This is accomplished through a combination of academic, military, athletic, and character development programs spread across the four-year experience. One of the primary ways we can develop these desired outcomes and give our future officers the skills they need to be successful is by having them conduct research that is relevant in today's highly technical, globally complex world.

At the Academy, the top priority for any research is cadet development. Our faculty and staff play a critical role in this effort. According to U.S. News and World Report annual rankings, USAFA is consistently in the top 5% for accessibility to professors. This accessibility and the desire for cadets to learn and grow in a research environment are critical ingredients to the successful programs that have made USAFA so successful. Just as cadets are learning that research does not always follow a textbook approach, USAFA faculty are getting the opportunity to develop new skills as educators so they can energize their classes and make them truly learning focused.

As our Air Force Academy cadets graduate to become officers of character for the U.S. Air Force, they are increasingly finding themselves in a volatile, uncertain, complex, and ambiguous world. Similar to conducting research, they will need to be able to take vague guidance on a task for which they are untrained, identify hurdles, and find a way to overcome them to be successful. They will be challenged to solve critical problems for the Air Force such as operating manned or unmanned aircraft, launching and controlling satellites, and protecting national security interests in the cyber domain. Future military operations will require innovative solutions to achieve our objectives in a resource-constrained environment. Because of their demonstrated success at USAFA, we know our graduates will rise to the occasion.

ACADEMY CENTER FOR CYBERSPACE RESEARCH

The mission of the Air Force is to fly, fight, and win in air, space, and cyberspace. Our ability to be successful in that mission in the cyber domain depends on having officers with deep technical knowledge and the ability to think strategically. The Academy Center for Cyberspace Research (ACCR) is a critical part of that effort.

"Cyber has the potential to disrupt our military's ability to project power around the globe and safeguard our national interests. Just as our dominance of airspace is essential for our ground forces, so too will our ability to navigate in the cyber domain be essential to our ability to project forces around the globe," said ACCR Director, Dr. Martin Carlisle.

To that end, the center supports activities that develop officers who will be the cyber innovators to defend our Air Force and nation. Cadets get both theoretical and hands-on education in offensive and defensive cyber warfare. They conduct research in current cyber topics with some of the nation's top cyber defense and private industry organizations including Intel Corporation, and they have the opportunity to put their learning into practice in the Academy's Cyber Warfare Training Range.

Combining coursework with hands-on, faculty-led real-world research and mentoring opportunities, small teams of cadets go through the entire research process—problem definition, literature review, project planning, data collection and analysis, and publication of results. Some project topics tackled by cadets in 2012–2013 Academic Year (AY) included performing a security analysis of a popular texting application for smartphones, determining if there was a correlation between income

and security of home wireless networks, and identifying code reuse in malicious software. Four cadets continued their research during an independent study, with the goal of having their work accepted to a peer-reviewed conference.

In cooperation with the Academy Center of Innovation and the Intel Corporation, Cadet First Class (C1C) Frank Adkins, C1C Luke Jones, and Dr. Carlisle are exploring how to automatically detect code reuse by malware. In combination with human intelligence, this can help identify who is responsible for an attack and also make it easier to quickly detect and prevent incidents. As part of this collaboration, C1C Nathan Hart, C1C Michael Winstead, and Dr. Carlisle are studying how to leverage capabilities of new Intel processors to defeat cyber-attacks that use "return-oriented programming," a mechanism used by attackers to defeat existing security measures in software.

One of the tenets behind the Academy's research successes is the belief that behind every successful cadet is a successful faculty member. Faculty research housed in the ACCR is helping to advance the state of the art in cyber. With support from the National Security Agency (NSA), Lt Col (ret) Del Christman, is leading an on-going research effort on the use of artificial intelligence to manage power grids. Using a newly developed neural network, he is seeking to have computers autonomously discover optimum strategies for dealing with intentional or unintentional faults in this critical infrastructure.

The Air Force Office of Scientific Research (AFOSR) is one of the Academy's longest supporters and has helped to fund decades of critical research at the Academy. One project currently funded by AFOSR is led by Mr. Allen Ott. Mr. Ott is exploring cyber situational awareness. His research combines data from many network activity logs to provide a real-time understanding of how a network is supporting particular missions, so defenders can assure mission capability during failures or attacks.

With support from the Defense Advanced Research Projects Agency (DARPA), Dr. Carlisle and Dr. Barry Fagin have developed a project called Ironsides. Ironsides is an authoritative domain name server, the "phone book" of the internet. Dr. Carlisle and Dr. Fagin utilize mathematical formal methods to prove their implementation of an authoritative domain name server is free from vulnerabilities which have plagued its predecessors.

In addition to research, ACCR provides opportunities for practical hands-on education and training in the Cyber Warfare Training Range, funded by the Department of Defense (DoD) Chief Information Officer and the National Reconnaissance Office (NRO). This facility allows cadets to practice with advanced cyber tools on an

isolated network. About one-quarter of the rising Third Class cadets learn cyber operations during the week-long "Basic Cyber" course taught in the Range by experienced upperclassmen with faculty oversight. All of the Academy's Fourth Class cadets get a hands-on cyber lab during their "Introduction to Computing" course. The Cyber Warfare Club and Cyber Competition Team also use the Range to explore more advanced topics.

The Academy's Cyber Competition Team has continued to do a tremendous job representing the Academy at various cyber competitions, garnering multiple awards over the past several years. What distinguishes the Academy's team from other USAFA teams is that they compete not only against other undergraduates, but also graduate students and industry professionals from around the world. They participated in eleven competitions during the 2012–2013 AY. Highlights included placing 1st of 331 undergraduate teams from the US and Canada in the New York University Poly Cyber Security Awareness Week Capture the Flag event, qualifying for the National Collegiate Cyber Defense Competition for the third consecutive year (only 10 colleges of 152 advanced to nationals), 2nd of over 80 US and Canadian teams in all categories and 17th of 575 worldwide in the Hack.Lu Capture the Flag event, and winning for a second consecutive year the NSA-sponsored inter-service Cyber Defense Exercise (CDX). In the CDX, the USAFA team built a network from scratch and then defended it against attacks by the National Security Agency (NSA) Red Team. Dr. Carlisle coaches this team of fifteen cadets and said, "We're incredibly proud of what our cadets accomplish as undergrads, competing against graduate students and industry professionals from around the world. It's a testament to their dedication and desire to learn skills to enable them to be outstanding cyber officers in the Air Force."

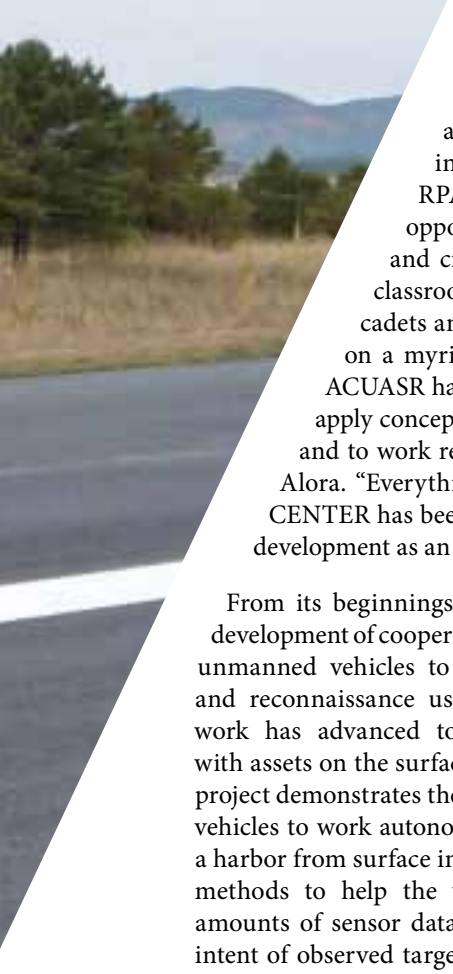
ACCR continues to seek to improve and expand its research, education, and training, not only among cadets, but also with other institutions. During the past AY, cadets helped develop a regional vulnerability assessment exercise for college students and mentored a high school cyber team. They also continued to develop relationships and collaborations with partners both inside and outside the DoD. "Our ambition is to be the best undergraduate cyber program in the country and to share that expertise with others," said Carlisle.

ACADEMY CENTER FOR UNMANNED AIRCRAFT SYSTEMS RESEARCH

As demonstrated many times in Afghanistan and Iraq, the Air Force intelligence strategy depends heavily on the deployment of remotely piloted aircraft (RPA) to perform intelligence, surveillance, and reconnaissance (ISR) missions in support of our warfighters. The Academy Center for Unmanned Aircraft Systems Research (ACUASR) has been leading research to develop technologies that improve and augment the current RPA capabilities through autonomy, cooperation, sensor estimate enhancement, and threat assessment.

In addition to military applications for RPA, domestic needs for unmanned aircraft systems (UAS) have been identified. The FAA Modernization and Reform Act of 2012 mandates the integration of UAS into our national airspace by September of 2015. Capabilities being developed at the Center not only enhance the performance of current and future Air Force missions, but are applicable for ensuring safer skies and more secure national borders with unmanned vehicles integrated into our national airspace.

The Center is multi-disciplinary by nature, employing faculty and cadets majoring in Aeronautical Engineering, Behavioral Sciences and Leadership, Electrical and Computer Engineering, Mechanical Engineering, System Engineering Management,



and Systems Engineering. The interdisciplinary aspects of RPA design and the increasing opportunities for RPAs in both military and civilian applications offer complex classroom and research challenges to cadets and require them to solve problems on a myriad of levels. ""Working with the ACUASR has provided me the opportunity to apply concepts I have learned in the classroom and to work real-world issues," states C2C John Alora. "Everything I have accomplished with the CENTER has been invaluable to my education and development as an Air Force leader."

From its beginnings, the Center has focused on the development of cooperative technologies for autonomous unmanned vehicles to perform wide-area surveillance and reconnaissance using heterogeneous sensors. This work has advanced to include cooperative behaviors with assets on the surface and under the water. A current project demonstrates the ability of unmanned underwater vehicles to work autonomously with our RPAs to protect a harbor from surface intruders. We are also determining methods to help the warfighter make sense of large amounts of sensor data by assessing the possible threat intent of observed targets. Another area of new research is assessing enabling technologies that help an RPA to navigate in areas when the use of the global positioning system is not possible.

Cadet projects expand on this research. One senior design project team has worked with the US Naval Academy and the US Military Academy to demonstrate cooperative behaviors among air, land and water surface unmanned vehicles. Another is working with industry to use the processor used in the common Android cell phones to provide low cost capabilities when paired with an RPA.

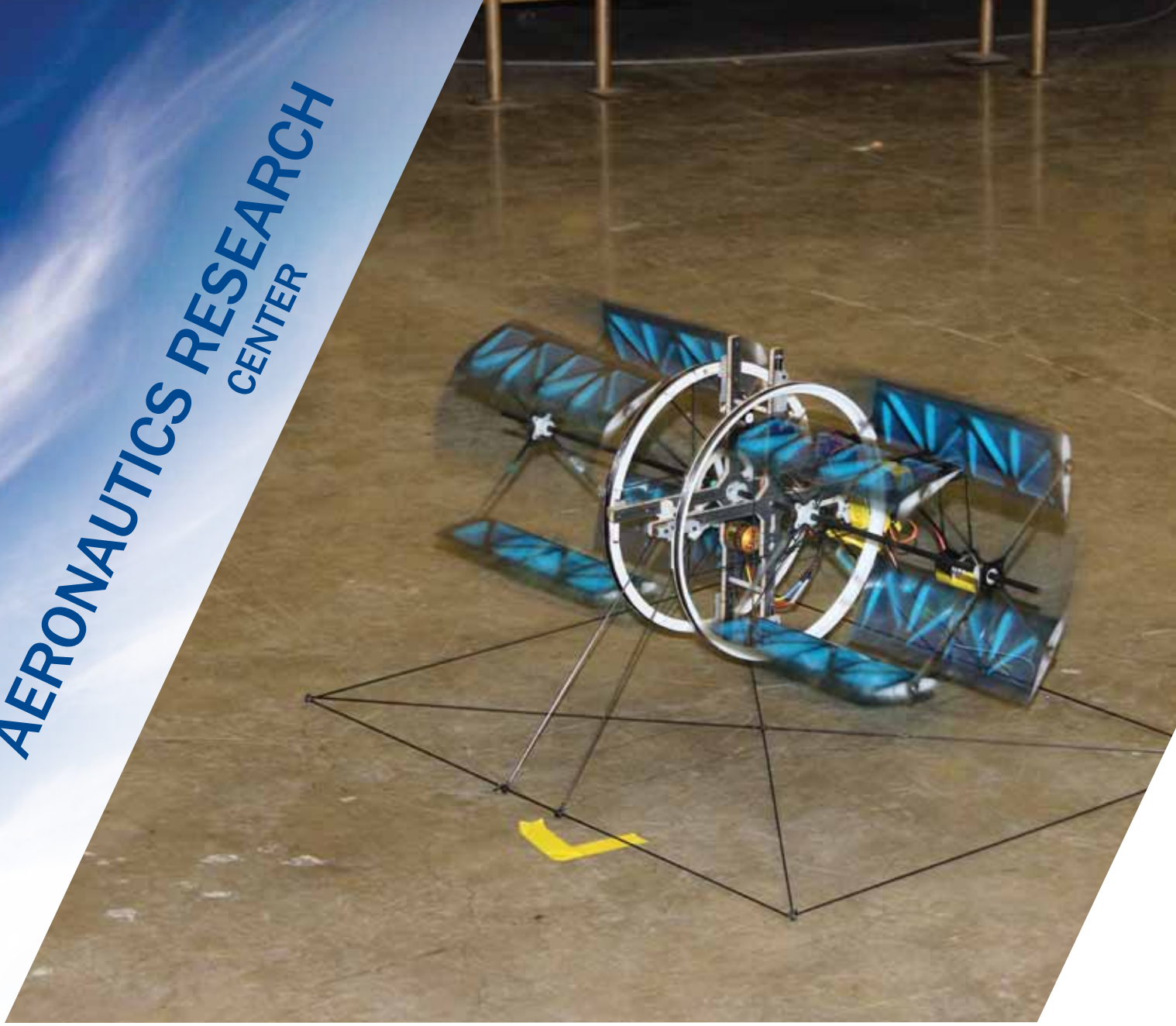
Mechanical Engineering cadets are creating a new way to model damage due to weapons effects on an aircraft, including shrapnel and overpressures. Current methods use fault trees to predict failure of a system due to a certain weapon effect. These methods require considerable testing and are binary in nature, in that they only provide the likelihood that the system will either still operate or will be completely nonfunctional. Many systems, however, retain some partial functionality when damaged. That partial functionality is not acknowledged within the fault tree methodology. Through the use of multiple computer aided design (CAD) and simulation computer programs, this cadet team is developing this new type of model for a radio controlled aircraft, which will be verified through experimental tests.

Other cadet projects involve developing innovative airframe designs for future RPAs. Cadets are designing a very durable small RPA called TuffFalcon to support the future research platform needs of the Center. Another

project involves refining their winning design of a 5th-Generation Aerial Target drone for USAF use. Still another aircraft design effort aims to provide a low cost, armed robotic wingman for manned aircraft. With the supporting facilities of five wind tunnels up to Mach 4+, new airframe designs can be tested in a variety of conditions.

"The increasing use of RPA systems to defend our nation's interests both here and abroad has created an expanded opportunity to perform critical missions while reducing operational costs. In the current fiscal environment, it is essential that our future Air Force leaders possess the ability to employ RPA systems effectively. The Academy Center for UAS Research helps our cadets and faculty learn this knowledge while furthering RPA capabilities. It is a privilege to be associated with the Center," says the Center's Director, Lt Col John Porche of the Department of Electrical and Computer Engineering.

AERONAUTICS RESEARCH CENTER



As one of the original research centers created at the U.S. Air Force Academy (USAFA), the Aeronautics Research Center (ARC) is one of the leading aeronautics research organizations in the world. It has carried on a tradition of providing the US Air Force and private aviation industries with proven, affordable research and development solutions for more than a half century.

Led by Dr. Tom McLaughlin, the center prides itself on being a leader in cadet-involved research. Cadets are involved in every research project conducted in the center, helping to tackle a range of issues and leveraging the center's impressive collection of wind tunnels including a new Mach 6 Ludwieg Tube, modeling and simulation assets, and dedicated faculty.

The ARC has steadily built its solid reputation among industry and fellow USAF and Department of Defense (DoD) partners and continues to diversify a wide-range of research capabilities.

During 2012–2013 AY, cadets and faculty conducted testing and analysis of Northrop Grumman (NG) micropropulsion technologies through collaboration between the Information Systems Sector and Defense Systems Division of NG. The ARC's wind tunnel facilities and analysis capabilities permitted characterization of the performance of Northrop proprietary technologies. Cadets, along with faculty and researchers, directly collaborated with senior NG engineers and managers

to develop suitable test plans, conduct tests, perform sophisticated engineering analyses, and presented results in such a manner that will assist in determining appropriate application of that technology. Success in the first task led the Air Force Research Laboratory Munitions Directorate to fund a second development effort.

The center continued its long and very fruitful collaboration with NASA Johnson Space Center. In recent years, the ARC has supported a range of initiatives on the Orion Crew Exploration Vehicle, including launch and launch abort, re-entry air data, and parachute recovery systems. This year, the focus was on Experimental Aerodynamic Development and Investigation of NASA Orion Flush Air Data System (FADS) to predict the air data state of the Orion Crew Module using 9 pressure ports on the heat shield. Cadets conducted wind tunnel evaluation of a scaled Orion Crew Module with offset FADS pressure ports, development of FADS prediction algorithms and calibration factors, determination of FADS feasibility, and prediction of FADS accuracy. Based on this effort, NASA has elected to implement a FADS system on Orion test vehicles. This work directly supports NASA's Orion development program and has direct safety of flight implications for astronauts.

NASA Johnson recently requested support for the Maraia Earth Return Capsule—a small, autonomous capsule designed for return from low earth orbit from the International Space Station (ISS). It will act as a flight test bed for various capsule systems as well as providing on-demand sample return for the ISS. To ensure NASA can continue mission planning of the Maraia Capsule, the ARC was tasked to define the baseline aerodynamic characteristics of the capsule in subsonic flight. This baseline characterization included lift, drag and moment data for the capsule at Mach 0.3 and Mach 0.45. The data will be used to examine the stability of the capsule in subsonic flight and provide a baseline for future Maraia modifications. Additionally, pressure data was obtained for future Computational Fluid Dynamics (CFD) analysis, and potential development of a Flush Air Data Sensor (FADS) system.

Another project cadets are working on is the Aerodynamic Development and Investigation of a New Drooped Leading Edge Concept to Improve A-10 Engine/Airframe Compatibility using a 1/20 scale wind tunnel model. The drooped leading edge concept was proposed by the ARC in June 2011 and is intended to replace the existing leading edge slat system currently on the aircraft. According to Dr. Tom Yechout, principal investigator, a series of wind tunnel tests is being conducted to optimize the drooped leading edge and fence configuration.

Col Neal Barlow, Aeronautics Department Permanent Professor and Head, summarized the collaboration with the A-10 System Program Office (SPO), "The A-10 work really hits the target in our push to be the undergraduate version of the 'Air Force's Aero Department'. In any situation where we can provide direct support to Air Force organizations, everyone wins. Cadets support the warfighter while developing their engineering skills, with the added benefit of seeing the importance and impact of their work. Customers such as the A-10 SPO obtain high quality data at minimum cost, and our faculty hone their engineering skills through relevant support to outside agencies".

The center also concluded a three-year collaboration with the Republic of Korea. Several Ph.D. researchers, staff and cadets performed an investigation into the performance of a tangent ogive at high angles of attack. The team found a means to eliminate loss of control at high angles brought on by vortex asymmetries. Though the problem has been well-known for decades, this is the first known instance where feedback flow control has been employed to overcome it. This effort was briefed to the Korean Agency for Defense Development, which seeks to further the development in follow-on efforts.

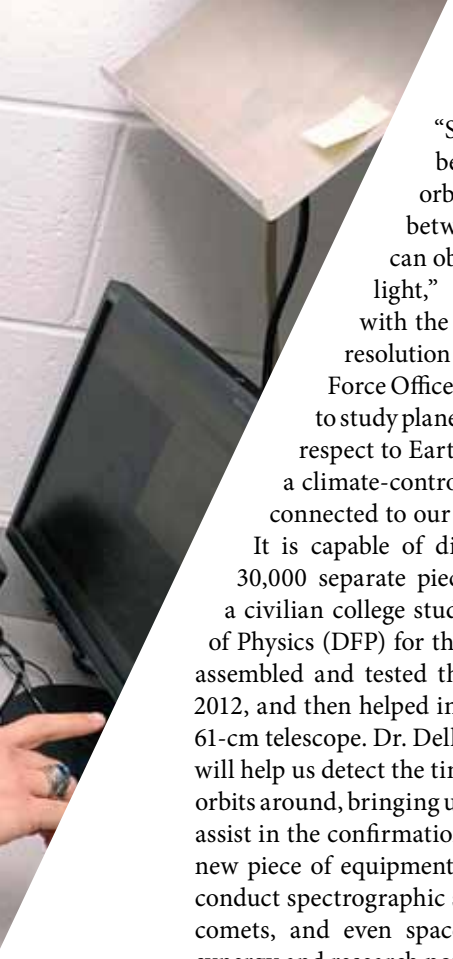
"The Korean collaboration is a great example of our efforts to maintain a long-term, basic research complement to the shorter term applied research efforts such as the A-10 work. It helps us develop our engineering prowess, and maintains a core complement of researchers available to mentor and lead cadets in their development as engineers and officers," said McLaughlin.

ASTRONOMICAL RESEARCH GROUP AND OBSERVATORY

USAFA's Astronomical Research Group and Observatory (ARGO) has a multi-faceted mission, directing all astronomy-related education for 300+ cadets across seven academic courses annually. In addition to its cadet research and education mission, the ARGO plans and conducts all astronomy public outreach events at the Observatory for over 300 members of the Front Range community each year.

"Cadet research at the USAFA Observatory develops future technical leaders who know how to apply the scientific method, as well as employ observational tools and techniques required of Air Force space scientists," says Director of the ARGO, Dr. Devin Della-Rose. "Feedback from former physics majors—now Air Force scientists—confirm that our approach is working." Under the guidance of Della-Rose, the ARGO directs an average of four cadet astronomy research projects each academic year and facilitates all cadet research conducted by the Center for Space Situational Awareness Research (CSSAR).

One key research area since 2008 has been the study of extra-solar planets, or "exoplanets" as they are usually called. In those five years, nine cadets have extensively studied five such planets and learned to achieve measurement accuracies comparable to professional research observatories. In 2012, C1Cs Samantha Latch and Gordon Spahr observed orbital changes in WASP-12b, a planet almost 900 light-years away! Such observations are critical to the study of how solar systems evolve. As future Air Force officers, tangible research results give our cadets the confidence that they can make original scientific and technical contributions to our military and country.



"So far, our exoplanet studies have been limited to planets whose orbital path crosses a direct line between their star and Earth, so cadets can observe the minute drop in the star's light," said Dr. Della-Rose. "However, with the current installation of a new high-resolution spectrograph, funded by the Air Force Office of Scientific Research, we'll be able to study planets with any orbital orientation with respect to Earth." This spectrograph is housed in a climate-controlled room of the observatory, and connected to our 61-cm telescope using fiber optics. It is capable of dividing visible starlight into over 30,000 separate pieces of data. Mr. Robert Hoglund, a civilian college student employed by the Department of Physics (DFP) for the last three summers, successfully assembled and tested the new instrument in summer of 2012, and then helped integrate the spectrograph with our 61-cm telescope. Dr. Della-Rose commented, "this new tool will help us detect the tiny wobble of a star as a large planet orbits around, bringing us closer to the goal of having cadets assist in the confirmation of new worlds." In addition, this new piece of equipment will enable cadets and faculty to conduct spectrographic studies of stars, galaxies, asteroids, comets, and even spacecraft orbiting Earth, enhancing synergy and research potential in the CSSAR.

During the summer and fall of 2013, Comet ISON will make its first-known pass around the Sun from the deep solar system. C1C Thomas "Will" Dickinson will lead a cadet research project to study the brightness, orbit, and spectrum of this comet. "I find cosmology and astronomy awe-inspiring – they attempt to answer perhaps the biggest questions that science is capable of answering – where did the universe come from and what is its future?" commented C1C Dickinson. "I will be 'doing' rather than just 'learning', and the research experience that I hope to gain will be invaluable if I become a physicist after commissioning. With the vast wealth of faculty knowledge and expertise along with superb facilities and equipment at my disposal, I am truly excited for my Firstie year!" he said.

During the spring 2013 semester, Cadet Dickinson partnered with C2C Jacob Hawkins on an independent research project to refine imaging techniques with CCD and CMOS camera sensors. Mentored by Lt Col Mario Serna, the cadets leveraged observatory assets to master calibration techniques for these sensors. This will be followed by in-depth radiometric studies of pulsating light sources concentrating on high frame rate, high resolution, and low light imaging. "The goal of this study was to ensure that I was fully prepared for my five-week cadet summer research project in 2013" remarked Cadet Dickinson. Researchers in DFP's Space Physics and Atmospheric Research Center (SPARC) will also benefit from the cadets' work, using the results of their calibration techniques to aid in the study of flickering aurorae.

As ARGO research continues to grow and diversify, future cadet and faculty researchers will be able to leverage the expanded coverage of CSSAR's Falcon Telescope Network to surpass the limits of what we can see in the Colorado Springs night sky. Dr. Della-Rose concluded: "I'm very proud of the legacy of ARGO cadet, faculty, and civilian research that continues to build. It's all been made possible by the unqualified support given to us and the USAFA Observatory by all levels of USAFA leadership."

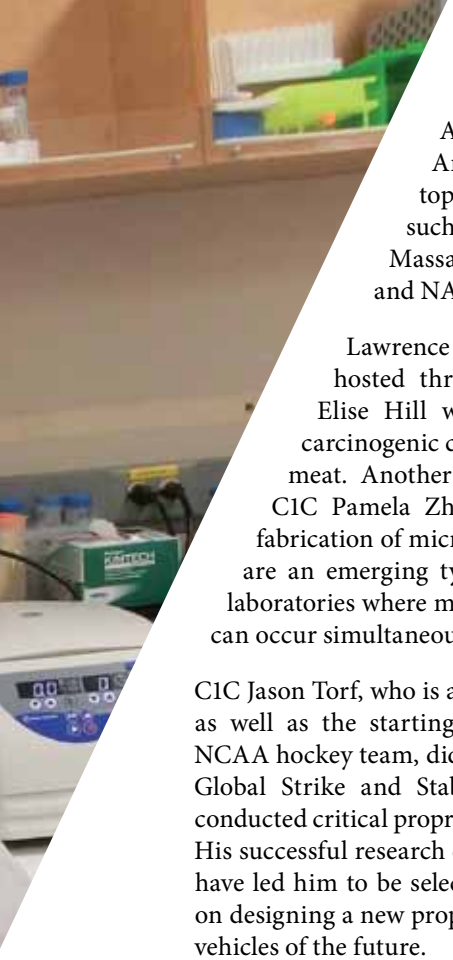
CADET SUMMER RESEARCH PROGRAM

The Cadet Summer Research Program has offered thousands of cadets the opportunity to conduct real-world research and to be mentored by some our nation's top technologists, scientists, researchers and leaders.

This program has proven itself by continually producing game-changing research results year after year; leading to publications in peer-reviewed journals, recognition by sponsors for the quality and impact of research, media success stories, and on-going patent and commercial technology transfer opportunities. This past year was no different.

"Strengths of the CSRP program include sponsors' commitment, remarkable administrative support, and exceptional cadets. Our sponsors are truly committed to making CSRP work. Each year, a number of sponsors visit USAFA to advertise their projects and solicit department interest. Each sponsoring agency has devoted personnel to work specifically with the service academies, and they actively participate in the selection of their cadets and projects," said lead CSRP representative Capt Michael Tanner.

For the 2013 summer, 173 cadets were selected to participate in the three to five-week intensive program—many gave up summer leave time as well to fully benefit from five-weeks in the program. Another appealing aspect of the program is the diversity of research opportunities available to participating cadets. These opportunities range from research projects in the heart of Intel Corporation's labs to top research opportunities at mission-essential commands such as the National Security



Agency and the Joint Base San Antonio to research with today's top industry and university partners such as the Boeing Corporation, the Massachusetts Institute of Technology and NASA.

Lawrence Livermore Laboratories hosted three CSRP cadets this year. C1C Elise Hill worked on a project to analyze carcinogenic chemicals found in cooked muscle meat. Another of her fellow cadet researchers C1C Pamela Zhang conducted research on the fabrication of microfluidic chips. Microfluidic chips are an emerging type of bio-medical micro-circuit laboratories where many experiments and lab cultures can occur simultaneously.

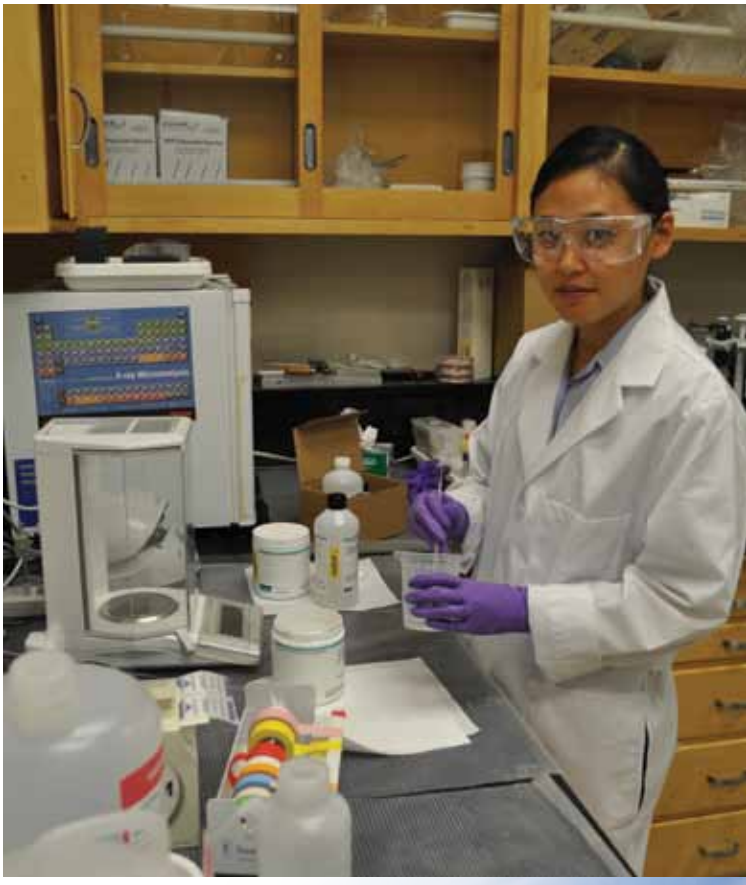
C1C Jason Torf, who is an aeronautical engineering major as well as the starting goal tender for the Academy's NCAA hockey team, did his CSRP experience at Boeing's Global Strike and Stability Control Labs. Cadet Torf conducted critical proprietary take-off analysis of the F-15. His successful research efforts from the CSRP experience have led him to be selected for a senior capstone project on designing a new propeller design for unmanned aerial vehicles of the future.

"I am extremely proud of how well our cadets have performed in their research enriched environments. Quite often I will receive accolades from CSRP sponsors regarding the maturity, professionalism and intellectual curiosity demonstrated while working on their projects," said the director of the Life Science Research Center, Dr. Don Veverka. "Some have even remarked it was hard to tell the difference between the cadets and graduate students with greater training and education—our cadets just simply exhibited a passion for science that made their CSRP experiences all that more rewarding!"

Many of the CSRP projects are continued as capstone or independent research projects when cadets return to the Academy for their senior year. Research successes from the CSRP program have also led to cadets presenting work at major conferences, publishing in peer-reviewed journals, and to a variety of patents and licensing opportunities.

Ultimately the hands-on learning benefits from participating in a CSRP project extend well beyond the classroom or the lab. For many, the lessons learned extend into their future careers with many seeking to leverage their research into graduate school after leaving the Academy.

"In addition to contributing to the development of our future officers, we receive outstanding feedback from many of the program's sponsors. Many who were concerned that five weeks would not be long enough to complete a given assignment were sent scrambling for more projects as cadets completed their work ahead of schedule. Other



sponsors reported that they asked the cadet to look at one portion of a project only to discover at the conclusion of the project that the cadet went far beyond the assignment simply because they could," said the Academy's Chief Scientist, Col Robert Kraus. "It's not just an internship—cadets are developing solutions for real-world customers."

CENTER FOR AIRCRAFT STRUCTURAL LIFE EXTENSION

According to the Air Force Times in 2013, the average age of aircraft in the Air Force is more that 24 years and some of the senior citizen aircraft such as the KC-135 tanker aircraft are today in excess of 50 years old. And the fleet is not getting any younger. In addition, the number of aircraft in the USAF inventory dropped about 9% between 2003 and 2012. The combination of fewer and older aircraft makes safe operation and maximum readiness of the remaining fleet a top priority, critical to the warfighter.

To safely answer modern day readiness challenges, the researchers and cadets of the Academy's Center for Aircraft Structural Life Extension (CAStLE) work on the front lines of a full spectrum of material degradation issues and their impact on structural integrity. Led by Dr. Gregory Shoales (Director) and Dr. James Greer, Jr. (Technical Director), CAStLE is leading the charge to satisfy the science and technology (S&T) needs of the USAF sustainment community. CAStLE's cutting-edge laboratory includes advanced material analysis, structural testing and Computer Numerically Controlled (CNC) fabrication equipment.

The center executes a wide variety of projects including new materials research, multiple aging aircraft structural teardown analysis programs, full-scale and component fatigue (crack growth) testing, validation of structural repair methods, corrosion

characterization and modeling research, load spectrum verification, complex structural modeling, energy harvesting, and even aircraft flight data collection. Funding for these efforts comes from a variety of sources including Air Force Sustainment Center, the Air Force Office of Scientific Research (AFOSR) and other DoD and non-DoD organizations.

"CAStLE supports our cadets' education by giving them hands-on, real-world structural sustainment experiences. Many USAF aircraft are seeing their third generation of pilots—some of our cadets will be flying airplanes their grandfathers flew. They are seeing first-hand the breadth and depth of the technical problems that must be addressed to keep these 'mature' aircraft flying for decades to come," said Greer. "Our cadets get to work with government and contractor teams charged with solving today's aircraft structural issues and, upon graduation, will head off to their Air Force jobs with a deeper appreciation of what's needed to sustain our warfighting capabilities."

Structural teardown analysis programs designed, planned and executed by CAStLE engineers with various aspects assisted by cadet projects, are used to destructively analyze retired USAF airframes to gain an insight into their condition not possible by any other means. Such insight in turn yields answers as to suitability of the entire fleet for extended safe service beyond original design service goals. Due to its previous record of successful research in this arena, CAStLE authored the USAF manual for teardown analysis programs and is currently considered to be the world's expert on the subject. Cadet contributions, through their research projects, added to this important USAF manual and they have been duly credited for their contribution. During the course of multiple teardown programs executed by CAStLE, cadets have been intimately involved in the evaluation of the fatigue residual life in fuselage lap joint panels, the evaluation of the static residual strength of similar fuselage lap joint panels, and real-life root cause analysis of the inspection indications. Multiple cadets have accomplished full "root cause" analyses of inspection indications which have become part of the formal report and data used by the C/KC-135 fleet managers.

"Since the academic program of all department cadets includes key elements of one or more CAStLE projects, CAStLE is an integral part of the cadet curriculum. The center gets to cherry pick from each and every project to extract those elements best suited to create a meaningful cadet experience of applying S&T solutions to DoD operational issues." said Shoales. "Our cadets publish their work and present their successful solutions to DoD leadership." Cadets further benefit from project partnerships with graduate students and professors from other universities, including the university partners of

the Technical Corrosion Collaboration sponsored by the Office of the Secretary of Defense's Corrosion Policy and Oversight office.

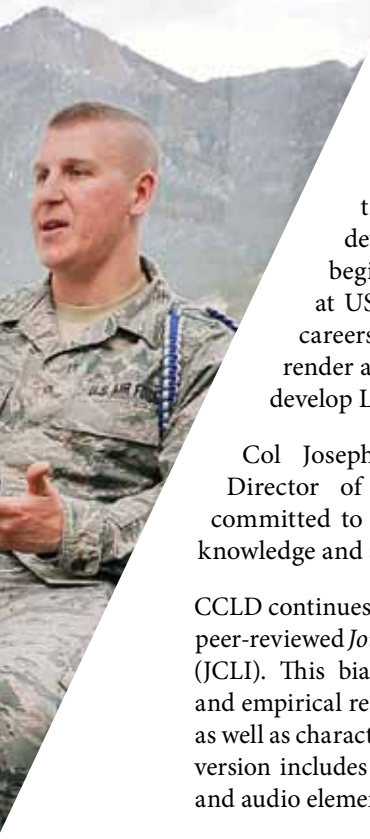
Another major thrust in the center's mission is its USAF Aircraft Structural Integrity Program support. Due to the center's recognized structural integrity expertise, researchers and cadets provide continuous support to multiple aircraft fleet managers to include A-10, B-1B, KC-135, T-38 and USAFA's own TG-16! These projects are varied and range from designing and validating repairs, performing residual life analysis, performing structural condition assessments, augmenting the current crack growth prediction database, and exploring material substitutions of legacy alloys.

Academy faculty benefit from CAStLE as well. "Our faculty's professional development is enhanced in much the same way as the cadets', by providing them with state-of-the-art tools to address current sustainment problems for the Air Force. Working with other DoD professionals in the field, our faculty are able to bring the most current and relevant technical issues into the classroom. This obviously benefits the cadets, but also has a 're-bluing' effect on the faculty, fostering their professional development, and increasing their value to the cadets and the Air Force," added Greer.

CENTER FOR CHARACTER & LEADERSHIP DEVELOPMENT

The Center for Character & Leadership Development (CCLD) fosters the growth of character and leadership in the cadets and staff at the United States Air Force Academy through the many programs it facilitates. Its mission is to advance the understanding, practice, and integration of character and leadership development while preparing cadets for service to the nation in the profession of arms. The CCLD staff is committed to creating and shaping a culture at USAFA that celebrates this development and promotes its integration across the broader Air Force. CCLD achieves this by providing world-class education and experiences for USAFA cadets and staff, enlightening and equipping future officers to advance lifelong habits of honorable living.

The 2012-2013 AY was critical in the Center's advancement toward being the Air Force's "First Call" organization in matters of character and leadership. CCLD formulated a three-part comprehensive assessment plan to align individual, programmatic, institutional, and Air Force developmental assessments. Presently, CCLD is making very constructive and concerted strides in assessing the impact of our programming across the institution as well as integrating character and leadership education with our mission elements in academics and athletics. Evaluation of center's programming relies on multiple



types of data, depending on the program itself and what data are potentially collectable. As part of this effort, CCLD is creating an assessment tool to be administered longitudinally to cadets. The new assessment tool will track each cadet's character and leadership development from the period before cadets begin basic training, throughout their time at USAFA, and after graduation as they start careers as USAF officers. This assessment will render a measure of USAFA's efforts as a whole to develop Leaders of Character.

Col Joseph Sanders, Permanent Professor and Director of CCLD, emphasizes that, "CCLD is committed to engaging in research that impacts both knowledge and application."

CCLD continues to extend its scholarly impact through the peer-reviewed *Journal of Character & Leadership Integration* (JCLI). This biannual publication showcases conceptual and empirical research from military and civilian scholars, as well as character and leadership practitioners. The online version includes several interactive features such as video and audio elements.

In addition, CCLD continues to build on two additional publication platforms *Scholar Briefs* and *Character Connections*. The *Scholar Briefs* are stand-alone monographs on topics of relevance to targeted audiences, and are available in hard-copy and electronic formats. In our most recent Scholar Brief we invited several resident scholars and Permanent Professors at the USAFA to provide a more academically in-depth explanation for CCLD's framework and its implications for developing leaders of character.

Character Connections is a quarterly online e-publication that presents a compelling character and leadership based question, and then invites relevant contributors to respond in two- to three- page influence pieces. The publication includes a comment feature that generates interaction among the participating readers. As an example, one issue addressed the question, "How does Failure Impact our Character", which was addressed by authors such as former skipper of the U.S.S. Greenwood, Commander (USN ret) Scott Waddle. Cmdr Waddle addressed his monumental failure in surfacing the Greenwood while a Japanese fishing boat was directly above and killed nine people, all of whom were under 17 years old.

Finally, after a very promising research project on character and leadership coaching, the center launched a robust leadership and coaching program. The Mosaic Coaching Program provides one-on-one expert coaching from certified staff members to cadets. The purpose is to help the cadet determine a viable strategy for strengthening a specific virtue or competency, and then hold the cadet accountable for practicing the behaviors which the cadet had specified. The Mosaic Coaching Program provides two forms of coaching: "Character Coaching," where fourth class cadets practice strengthening one specific virtue (e.g., courage, humility, duty); and "Leadership Coaching," where second class cadets in a front-line leadership role practice strengthening one specific leadership competency (e.g., Takes Care of People; Builds Teams and Coalitions) while receiving upward feedback from their subordinates. Results demonstrated that 93% of the fourth-class cadets who received Character Coaching 'absolutely agreed' that "As a direct result of the coaching relationship that I had with my Character Coach, I became significantly more competent in the specific virtue that I had wanted to strengthen." Furthermore, 73% of the second-class cadets who were in a front-line leadership role absolutely agreed that "The coaching experience further strengthened my ability in the leadership competency which I had targeted."

Specifically, CCLD is extremely fortunate to have Col Tom Drohan, Permanent Professor and Head Dept. of Military Srategic Studies, serve as a visiting scholar assigned to the center. Col Drohan is working on a book that seeks to understand the blending of character and ethics, comparative strategic culture and the combined effects of strategy applied to security crises.

The CCLD with its many goals for its programs, events, and scholarship expansion is always striving for innovative instruction and research into the disciplines of character and leadership, to continuously learn and adjust to the demands of change, and to challenge established world views about character and leadership.

CENTER FOR K-12 STEM OUTREACH AND RESEARCH

The U.S. Air Force Academy's Center for K-12 STEM Outreach and Research is working diligently to be the "spark" that kindles the fire, setting K-12 students on the path to a STEM career, supporting K-12 educators and community STEM organizations in their missions, and developing exportable, scalable and flexible STEM models for our national community.

U.S. K-12 students increasingly lag behind global competitors in math and science competency and the U.S. is graduating fewer STEM students with bachelors, masters and PhDs. According to the 2012 U.S. Congress Joint Economic Committee report on STEM Education, US 15-year olds rank 25th in math and 17th in science on the Programme on International Student Assessment (PISA) exam. This report also cited evidence that students' struggles with STEM start early in the education process with lack of K-12 STEM curriculum, lack of K-12 educators with STEM training, lack of access to hands-on activities, and lack of STEM mentors.

In his 2013 State of the Union address, President Obama said that our economy relies upon a foundation of skilled workers, trained to meet the needs of growing sectors such as science and technology.

Through a regional partnership with the Colorado Consortium for Earth and Space Science Education, the USAFA Center for K-12 STEM Outreach & Research leverages investment dollars from the National Defense Education Program (NDEP)

with existing STEM organizations and content providers, industry and foundation gifts and support, and volunteerism from within the USAFA Cadet Wing and faculty to provide world-class STEM opportunities for K-12 students across Southern Colorado.

Over the past several years, USAFA has exponentially grown its STEM outreach efforts. Partnered with over a dozen local and national agencies, the center offers opportunities to more than 200 schools in more than 50 school districts, supports more than 700 educators, and combined with the cadet-led Cadet Wing STEM Outreach Club, has reached more than 200K students in the past 18 months.

The combination of both direct and partnered outreach is a critical component to the continued success of the center, which is led by Department of Chemistry instructor, Lt Col Rob Passinault.

Cooperative Research and Development Agreement (CRADA) partner, 17-year old Sara Volz, is an example of USAFA's direct STEM outreach efforts. Volz is doing research on the growth of better algae bio-fuels and was USAFA's first high school level CRADA. Her research with USAFA faculty Dr. Don Veverka and Dr. Timm Knoerzer, led to her selection as the 2013 Intel Science Talent Search winner. With the $100,000 prize, Volz will attend Massachusetts Institute of Technology after she graduates from high school.

Other direct outreach includes lab tours, workshops, and traveling demonstrations including Physics is Phun, Chemistry Magic Shows, and STEM at the USAFA Observatory.

Another outreach effort comes through the volunteer, cadet-led efforts of the Cadet Wing STEM Outreach Club. Led by founder, C1C Victor Lopez, the club has reached thousands of students. Cadets volunteer in classrooms, help judge regional science fairs and events such as BEST Robotics and Sea Perch competitions, and attend STEM festivals and regional airshows. Cadet Lopez also developed a special hybrid rocket demonstration program that was awarded 1st place at the AIAA International Student Paper Competition, K-12 STEM Outreach Category, and the club has begun conducting demonstrations in Spanish at ethnically diverse schools in Southern Colorado.

Partnered outreach is another critical component of the center's efforts. The K-12 STEM Bootcamps for Educators is a prime example. This multi-day workshop offers hands-on training, continuing education credits, and take-home classroom STEM materials to an average of 100 K-12 educators every summer. Workshop partners have included the Challenger Learning Center of Colorado Springs, which organizes the bootcamps for the Academy. Some of the past workshops presenters include NASA,

the Federal Aviation Administration, the U.S. Navy Sea Perch program, and LEGO Robotics. The fourth annual K-12 STEM Bootcamps for Educators sold out of spaces in record time in early 2013 - nearly six months before the camps were scheduled.

Other partnerships include support of the annual Audience with An Astronaut event with the Space Foundation and the Cool Science Festival.

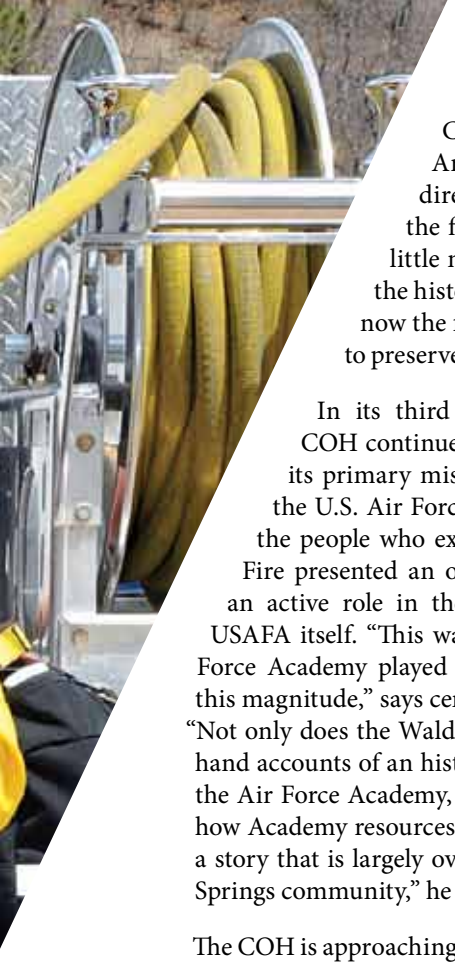
Finding creative ways to engage students in STEM is also critical to the program's success. The USAFA STEM Outreach mascot Ms. Aurora Phd is a tool to connect with students via social media. Aurora supports USAFA STEM events as well as regional and national STEM events. Ms. Aurora Phd helps students and even adults get comfortable and have fun with science in a non-threatening way. In 2013, via social media, Ms. Aurora Phd partnered with three NASA astronauts in USAFA's first "Ask An Astronaut" event. USAF Col Jim Dutton, pilot of STS-131, USAF Col (Retired) Jim Voss, who flew on four space shuttle missions and served on the International Space Station as part of Expedition-2 and Joe Tanner, who flew on four space shuttle missions; took questions from 20 K-12 schools from across the nation and filmed selected responses to share on social media.

"We believe in an all-of-the-above approach to getting STEM groups to work alongside each other, educating, training, and inspiring our nation's future scientists, engineers, pilots, and astronauts. The long term payoff may not be realized for years, but the motivation and enthusiasm of the students, our cadets, and STEM leaders is a positive sign of great things to come," says USAFA Chief Scientist, Col Bob Kraus.

CENTER FOR ORAL HISTORY

On the afternoon of June 26, 2012, cataclysmic weather conditions transformed a mountain fire confined in the ridgeline southwest of the U.S. Air Force Academy into a raging firestorm. In a matter of minutes, a wind-driven inferno roared down a series of canyons and into the Mountain Shadows subdivision, consuming 346 homes, killing two people, destroying millions of dollars of property, and forcing the evacuation of much of the west side of Colorado Springs. The next day, U.S. Air Force Academy Superintendent Lieutenant General Michael Gould, appeared on television in efforts to reassure parents of the class of 2016 that all was well. Not only would inprocessing for the incoming class, scheduled for the next day, continue as planned, but he stressed that the U.S. Air Force Academy was safe, despite the precautionary evacuation of USAFA housing areas in Pine and Douglass Valleys.

The content of Gen Gould's press conference is only part of the history of the Waldo Canyon Fire, however, a history that is now being preserved by the USAFA Center for Oral History. Earlier that day, herculean efforts by Academy firefighters limited the damage to less than 150 acres of grassland on Academy property. Capitalizing on an eight-bulldozer-wide firebreak created by Army engineers loaned from nearby Fort Carson, water and fire-retardant airdropped with pinpoint precision, and firefighting assets on loan from the Academy airfield, USAFA crews stopped the fire as it stretched the limits of hastily-created firelines created to halt the spread of destruction. If the USAFA firefighters had failed in their mission, fire forecast models predicted that there was little to prevent the blaze from destroying Pine Valley, Douglass Valley, the Community



Center and threatening the Cadet Area itself. The successful USAFA-directed efforts to halt the spread of the fire, efforts otherwise relegated to little more than an obscure footnote in the history of the Waldo Canyon Fire, are now the focus of the COH, which is trying to preserve this important story for posterity.

In its third year of formal operations, the COH continues to be successful in carrying out its primary mission of preserving the history of the U.S. Air Force Academy through the voices of the people who experienced it. The Waldo Canyon Fire presented an opportunity for the COH to take an active role in the preservation of the history of USAFA itself. "This was the first time that the U.S. Air Force Academy played a significant role in an event of this magnitude," says center Director Dr. Bob Wettemann. "Not only does the Waldo Canyon Fire let us capture first-hand accounts of an historical event that literally touched the Air Force Academy, but we have a chance to preserve how Academy resources helped stop the spread of the fire, a story that is largely overlooked by the greater Colorado Springs community," he added.

The COH is approaching the preservation of this historical event the same way it would record the events of a military campaign—collecting of first-person narratives from individuals involved at the strategic, operational, and tactical levels. "The strategic decisions regarding fighting Waldo Canyon Fire were made by the Type-1 Incident Command," Wettemann explains. "Once units were deployed, things shifted to the operational level, where local commanders, in this case the USAFA Fire Authorities, were responsible for stopping the fire from spreading any further." With the key events in the decision-making process recorded, then the narrative shifts to the numerous actors who had a stake in the fighting of the fire on the tactical level. "That story not only includes the experiences of those the firefighters, but all who were evacuated and the handful of cadets that were tasked with going door-to-door in Douglas Valley to ensure that all the residents had gotten the word to evacuate."

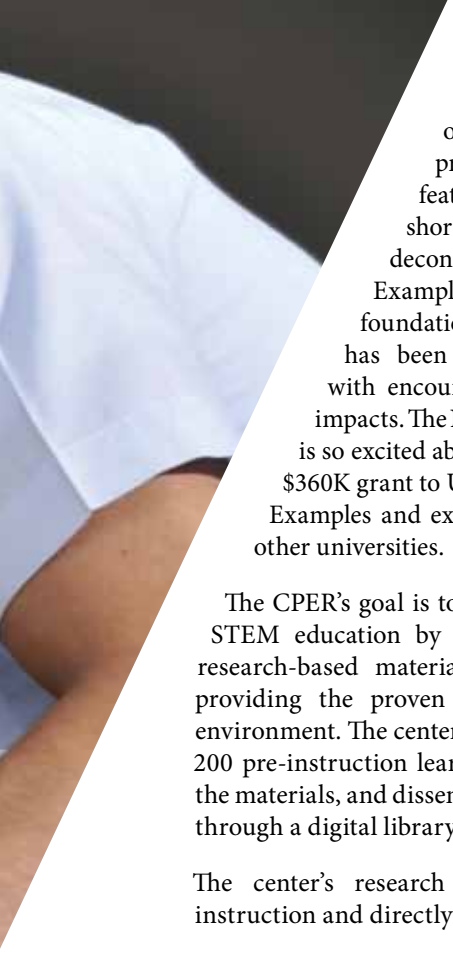
In the press conference that he gave in early July after firefighters contained the blaze, Gen Gould spoke of the Waldo Canyon Fire event as a test of USAFA's resilience. "The story of USAFA's efforts to fight the Waldo Canyon Fire is not only a test of resilience," opined Colonel Mark Wells, Permanent Professor and Head of the Department of History, "it is another instance of USAFA leadership and character on display. Those of us who were evacuated, will now know that USAFA played a significant role in stopping the further spread of the fire." These lessons, preserved by the COH, will provide Air force leaders of character with real examples of courage, moral fortitude, and integrity that will serve to inspire them during their future careers.

CENTER FOR PHYSICS EDUCATION RESEARCH

The Academy's Center for Physics Education Research (CPER) is on the frontline of transforming the Academy's learning and teaching environment, providing a platform on which faculty and students can become fully engaged in physics, physics education, and Science, Technology, Engineering, and Mathematics (STEM) endeavors. Housed in the Department of Physics, CPER is led by Maj Nathan Terry and Distinguished Scholar, Dr. Gregor Novak. The center directs multiple research efforts with the goal of improving STEM education not only in the USAFA classrooms, but nationwide as well.

"When trying to assess the efficacy of any pedagogical strategy, it is important to appreciate that the choice and implementation of a particular teaching method will affect student and faculty attitudes and motivation as well as learning outcomes" said Dr. Novak.

Building upon the success of its internationally recognized flagship project, Just In Time Teaching (JiTT) and JiTT's extension through the center's Worked-Examples pedagogy, CPER has focused its efforts on creating research-based materials to enable any school and any instructor to take advantage of USAFA-proven techniques. CPER has developed a pilot version



of a pedagogical approach using pre-instruction learning objects and featuring an expert's treatment of a short problem task for the learner to deconstruct and analyze. This "Worked-Examples" approach, implemented as the foundation for all core physics courses, has been tested on over 4,000 students, with encouraging results and wide-reaching impacts. The National Science Foundation (NSF) is so excited about this work that they provided a $360K grant to USAFA to further develop Worked-Examples and expand its implementation to three other universities.

The CPER's goal is to impact USAFA and the nation's STEM education by further developing a library of research-based materials that will aid instructors in providing the proven benefits of an active learning environment. The center has begun the task of developing 200 pre-instruction learning modules, classroom-testing the materials, and disseminating the materials nationwide through a digital library funded by the NSF.

The center's research is looking beyond classroom instruction and directly into the minds of the students.

Cognitive science and education research suggest learning that incorporates metacognitive knowledge and skills leads to longer lasting outcomes. The research also suggests that metacognitive skills can be acquired with curricula that help students develop an awareness of their inquiry process and the ability to reflect on what they are doing. Such curricula better meet the needs of "millennial" students. (See for example, Jausovec, N. *Metacognition in creative problem solving, 1994).* CPER researchers are using the results of existing metacognition research to formulate curricula to improve and strengthen student inquiry skills.

All of these efforts produce future Air Force officers possessing better critical thinking skills in technical and non-technical problem solving. Instead of leaving their physics courses with a handful of memorized equations, they will leave better able to attack any intellectual problem.

"With a concept-oriented approach to a concept-oriented science, the equations became the tools they are supposed to be instead of the solutions to a test," remarked one student.

Based upon software developed by a multi-university group (USMA, USAFA, Emporia State, Appalachian State University and Georgia Gwinnet College), CPER is creating and evaluating computer-modeling exercises for an introductory physics course that will develop students' metacognitive knowledge and skills. Prototype modules are currently being tested by several hundred cadets in USAFA's introductory mechanics course. With these prototypes in development, students will be guided in the construction and testing of models to represent physical

scenarios. Supported by video-game quality simulations, students will be able to practice hands-on implementation of the scientific method, begin to understand how science develops laws of nature, and acquire a more permanent understanding of the physics content through a guided-inquiry process. It is important to help students see that "incorrect" answers are not evidence of failure on their part but are stepping stones in the learning process.

CPER research efforts are also looking to the future. The center is exploring ways to exploit the capabilities of mobile technology to address a classroom issue: improving the frequency and quality of in-class student engagement. The center's goal is to elevate the frequency and quality of meaningful classroom engagement in physics core classes. CPER researchers are working to develop a mobile technology based system for monitoring student participation in all classroom activities on a daily basis and providing real-time scoring data to instructors through a mobile device such as an iPad™, iPod Touch™ or Android™-based device. Students will be rewarded for showing evidence of classroom engagement. The system will consist of a server and in-class mobile devices with which instructors will assign credit and monitor participation throughout the semester. The data will be fed back to the mobile devices to inform the instructor about the level and timing participation by the students. The data will also be analyzed and compared to other metrics such as test results and student surveys to improve the design of the pre-class assignments and the in-class activities. Forty cadets are currently involved in a study of this engagement technique and gains are already being seen over similar control groups.

"For the first time, we are seeing a quantified link between particular classroom activities and performance on graded assessments. The observed links highlight the importance of quality engagement and provides hints as to which types of engagement contribute to deeper conceptual learning," said Department of Physics instructor and CPER researcher, Lt Col Steven Novotny.

CENTER FOR SPACE SITUATIONAL AWARENESS RESEARCH

The space domain in which we operate is extremely large and relatively sparsely populated, but collisions can and do happen. The aftereffects can degrade operations in the space domain. In January of 2013, debris from the 2007 Chinese anti-satellite test collided with a small Russian retro-reflector satellite. This collision was not anticipated and only confirmed about six weeks after the fact. One can only imagine the ramifications if an operating satellite were to be rendered inoperative due to a purposeful collision or event. Thus space situational awareness (SSA) is vitally important to safe and free operating conditions in space.

The Department of Physics Center for Space Situational Awareness Research (CSSAR), led by Dr. Francis Chun, provides cadets and faculty with world-class capabilities and facilities to conduct cutting-edge SSA research. A hallmark of these capabilities is a global network of small aperture optical telescopes for non-resolvable space object identification called the Falcon Telescope Network (FTN). Funded by USAFA and the Air Force Office of Scientific Research (AFOSR), CSSAR is partnering with educational institutions around the world to build an initial FTN of 12 fixed telescope observatories and two mobile observatories. Equipment for the observatories has either been received by CSSAR or is being manufactured with delivery during FY13/14. First light for the FTN is anticipated in the Fall of 2013 with the first three nodes at Otero Junior

College in La Junta, Colorado; Penn State University, and Mamalluca Observatory in Vicuna, Chile.

Cadets continue to take active roles in the center's research. C1C Brandon Mueller had a summer research project at the Maui High Performance Computing Center (MHPCC) developing a model of the FTN using DoD supercomputers. He adapted an Air Force Research Laboratory (AFRL) photometric modeling code to run in a parallel fashion using the HPC Portal, a new entry point to easily run code on high performance computers. MHPCC used Cadet Mueller as a beta tester for the portal leading to improvements to a DoD-level capability that can revolutionize how the military uses HPC assets. Indeed, Mr. David Morton, Air Force Director for MHPCC lauded Mueller for making "valuable contributions to MHPCC … His professionalism, intensive use of the interface and constructive feedback to the development team was considered very valuable to MHPCC and helped greatly to refine the capabilities of the Portal interface."

C1C Peter Jackson, C1C Andrew Oury, and C1C Shane Bruski (Astronautics major) led a second summer research project deploying with CSSAR's 20-inch mobile telescope observatory to Kirtland Air Force Base, New Mexico. The cadets developed robust procedures for properly aligning the telescope onto the sky and demonstrated satellite tracking and photometric measurement techniques. Additionally, they trained AFRL researchers on mobile telescope operations allowing AFRL to use the system independently. Cadets Jackson and Oury then conducted simultaneous observations on a select set of satellites, coordinating efforts between five federal agencies. Cadets Lance Wilhelm and Mueller developed photometric models of these satellites to compare to any real-world measurements taken. A key improvement that they made was the ability to ingest actual satellite quaternion attitude data into the photometric simulation, thus removing one key unknown in the model results.

C1Cs Ian Ferguson and Christopher Earp-Pitkins continued to refine spectral measurement techniques on geosynchronous satellites using a slit-less spectroscopy technique. Ferguson and Earp-Pitkins obtained some unique results showing that the spectral signatures of stable geosynchronous communication satellites are indeed different pre- and post-midnight compared to midnight.

CSSAR also led cadet research in two new areas: polarization measurements of geosynchronous satellites and rules-based prioritization for the FTN. C1Cs Renee Bohac and Cameron Harris integrated a new polarized beam splitter onto a 20-inch mobile telescope observatory, calibrating the polarizer against a known source, and then observing geosynchronous satellites. Results from this project will be foundational for new CSSAR capability.

CSSAR cadets present their research results at AFRL workshops on non-resolvable space object identification techniques, providing them "an excellent opportunity to showcase their research in an informal setting to an audience of internationally renowned experts in satellite characterization," said Chun. "It also reinforces to our colleagues in the SSA research community that the Academy values a strong cadet education program focused on space domain awareness.

In partnership with Electronic Systems Center and MITRE, CSSAR is making progress in developing an initial Cadet Space Operations Center (CSOC) capability to support the FTN first light. Air Force Space Command (AFSPC) is also lending their support by providing a junior analyst, 1Lt Drew Safronoff to help manage the CSOC program. In return, Safronoff is learning valuable skills in satellite tracking and signature measurement as well as program management. Additionally, CSSAR is receiving support from the Universities Space Research Association (USRA). Through a Cooperative Research and Development Agreement (CRADA), USRA's Ms. Kimberlee Gresham is conducting research on the spin rate of upper stage rocket body debris and participating in satellite photometric observations.

CSSAR continues to make strides in affecting Air Force space research. In February 2013, Dr. Michael Dearborn, 1Lt Fulcoly (USAFA 2010 graduate), and 1Lt Safronoff deployed with the Academy's mobile telescope to Plentywood, Montana to conduct the northernmost latitude observations. Combined with telescopes located at the Academy, Albuquerque, Maui, and Ohio, the USAFA-AFRL team was able to obtain tens of thousands of photometric measurements, providing a wealth of data enabling exquisite satellite characterization. As valuable as those measurements are however, the most beneficial piece is that CSSAR is providing the Air Force with officers with a sound technical background in space.

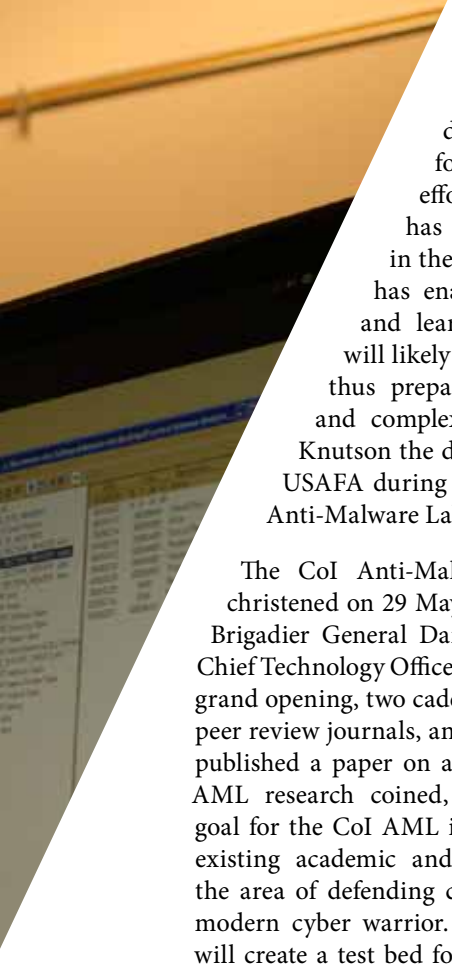
CENTER OF INNOVATION

The Department of Homeland Security, Science and Technology Directorate Center of Innovation (CoI) was established in 2008 at the US Air Force Academy (USAFA). The CoI is a leader in championing game-changing innovations for the United States Government (USG). The CoI has established noteworthy public-private partnerships with market-shaping companies such as Intel Corporation and the IBM Watson Research Center.

The value of these novel public-private partnerships is three-fold: the government is privy to the future and direction of market-shaping research technology; private industry discovers the technology needs of government; and USAFA cadets benefit from unprecedented research opportunities with leading researchers from the private sector.

USAFA cadet involvement is the cornerstone of every research relationship the CoI cultivates with its private industry partners. USAFA cadets are mentored by world-class innovators conducting cutting-edge research both at USAFA and within industry.

The evolution of technology is fueling a growing portfolio of capabilities. The market demand is being driven by the web 2.0/3.0 millennial generation, who view cyberspace as their natural habitat. USAFA cadets view cyberspace as their natural



domain. USAFA cadets have been forever impacted by the CoI's efforts. "Innovative thinking is what has made our US Air Force the best in the world. The Center of Innovation has enabled others and me to explore and learn about new technologies that will likely shape conflict in the 21st Century, thus preparing us to lead in a nonlinear and complex environment," said 2Lt Chris Knutson the day following his graduation from USAFA during the official ribbon cutting of the Anti-Malware Lab (AML).

The CoI Anti-Malware lab (AML) was officially christened on 29 May 2013 by the Dean of the Faculty, Brigadier General Dana Born and Intel Corporation's Chief Technology Officer, Justin Rattner. At the time of the grand opening, two cadet teams were finalizing papers for peer review journals, and an Intel Corporation researcher published a paper on a new capability originating from AML research coined, Provenance. The public-private goal for the CoI AML is to compliment and supplement existing academic and military training programs in the area of defending cyber-attacks and defense for the modern cyber warrior. This unique research laboratory will create a test bed for the most current hardware and software innovations being researched at Intel Research Labs and give USAFA cadets and our USG agency partners unprecedented access to anti-malware research technology.

"One of the most exciting things the Center of Innovation has to offer USAFA cadets is the one-of-a-kind experience in the private sector. For me, it is very rewarding to see these cadets being mentored by and working alongside leading researchers who are focused on game-changing innovations. Our USAFA cadets, through the CoI, are provided the tools to develop into leaders of character – leaders who will have a great impact on the evolution of the Air Force and DoD operations," says Dr. Terry Pierce, Director, of Center of Innovation.

During the 2012-2013 academic year, the CoI requested an increase in funding for cadet summer research projects due to the impact of Sequestration. The CoI tripled the summer research budget and sponsored 18 cadets for participation in summer research. Eight cadets conducted research with Intel Corporation's leading scientists at Intel Research Labs in Hillsboro, Oregon and Santa Clara, California. USAFA cadets studied leading-edge futurism, anti-malware, silicon photonics, new web crawling technologies and new hardware security solutions. Cadets were sent to the Department of Homeland Security (DHS) Centers of Excellence, DHS Headquarters, Department of Defense agencies and the White House. Feedback about USAFA cadets is always impressive. "I purposefully provided the cadets vague information just to see what they would do with the information. I was simply astonished when I received

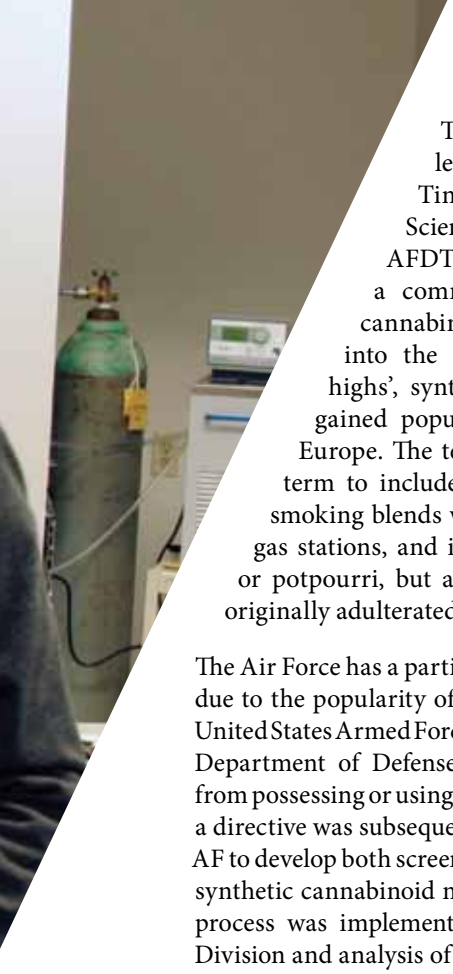
their information" said one DHS director. Brian David Johnson from Intel Corporation provided the following assessment of Cadet David Jorgenson; "He proactively demonstrated innovation and provided creative, valuable inputs to the Tomorrow Project team efforts. Disciplined and prolific: he quickly and actively embraced the futurecasting and science fiction prototyping concepts and delivered timely, compelling stories/blogs/opinions. Upon graduation, the CoI hopes USAFA cadets can leverage their research experiences to champion solutions to tomorrow's threats.

The CoI has realized its first significant breakthrough with a disruptive innovation from Intel Corporation. The CoI and Intel Corporation have collaboratively researched a new hardware security technology. The results of the research were released publicly by Intel Corporation in June 2013 at a conference, and the CoI was cited in the research results. For the first time in history, the US Government was the first adopter of an Intel Corporation technology before release through their collaboration with the center. The CoI is working with several government agencies to integrate this game-changing hardware security into their enterprise solutions.

Chemistry Research CENTER

The Chemistry Research Center (CRC) within the Department of Chemistry (DFC) at the United States Air Force Academy remains a vibrant force in the exploration of chemistry and the scientific education of the next generation of Air Force officers. Under the leadership of Dr. Scott Iacono, the CRC has embarked upon novel projects that have a direct impact on operations in today's Air Force. Dr. Iacono oversees one of the top chemistry research facilities in the Nation for primarily undergraduate institutions. The CRC utilizes in excess of $3M in Department instrumentation and secured nearly $450K in research funding during the 2012-2013 academic year. The CRC has continued to excel in a broad area of materials-based chemistry research as evidenced by the robust publication record and strong ongoing scientific relationships with partner agencies such as the Air Force Research Laboratory, the Air Force Office of Scientific Research, and the Defense Threat Reduction Agency as well as academic and national laboratories. Active cadet-centric research programs with DFC faculty, CRC research staff, post-doctoral associates, and visiting Fellows include conjugated polymers for organic electronics displays, energetic materials for next-generation munitions, rapidly deployable portable chemical/biological sensors development, and structural composites for propulsion applications.

The past year has seen a significant advancement in the scope of collaborations with the Air Force Drug Testing Lab (AFDTL), Lackland AFB, TX. In particular, the CRC began a technical collaboration with AFDTL's Drs. Dennis Lovett and Enrique Yanes, who were interested in engaging CRC faculty, staff, and cadets in a project related to synthetic cannabinoids (aka "Spice").



The first foray involved the efforts led by DFC faculty member Dr. Timm Knoerzer and CRC Staff Scientist Mr. Joe Levisky to assist AFDTL on a project for the search of a common metabolite from synthetic cannabinoids. Since their introduction into the market place in 2004 as 'legal highs', synthetic cannabinoids have rapidly gained popularity in the United States and Europe. The term 'Spice' has become a generic term to include the entire class of "legal high" smoking blends which are sold on the internet, in gas stations, and in local tobacco shops as incense or potpourri, but are actually inactive plant matter originally adulterated with synthetic cannabinoids.

The Air Force has a particular stake in this area of research due to the popularity of Spice which had extended to the United States Armed Forces and resulted in the United States Department of Defense banning all military personnel from possessing or using synthetic cannabinoids. Therefore, a directive was subsequently issued by the Secretary of the AF to develop both screening and confirmation analyses for synthetic cannabinoid metabolites in urine. The resulting process was implemented at the AFDTL Investigations Division and analysis of service member samples began in March 2012.

"This is clearly an important problem facing the armed services and we are pleased to be called upon to provide the scientific expertise to address the issue," Dr. Knoerzer said. "Fortunately, we have the facilities and know-how to accomplish this vital mission."

During her Cadet Summer Research Program, C1C Alexa Gingras teamed up with Drs. Lovett and Yanes to further explore how a combination of state-of-the-art analytical techniques could facilitate identification of synthetic cannabinoids.

C1C Gingras improved the sensitivity of the Air Force's drug tests four-fold and devised a drastically shortened method of preparing urine samples for analysis. The real payoff is that as the spice market continues to evolve, this new paradigm would eliminate the need to monitor the presence of a vast array of spice metabolites. Consequently it would be unnecessary to wait for new spice reference standards to become commercially available. This work successfully led to a 2013 high-impact publication in *Forensic Science International*.

Ultimately, this seminal work attracted attention from the local news media as well as the faculty leadership at USAFA. C1C Gingras' efforts resulted in her achieving distinction with receipt of the USAFA Basic Science Division Moore Award as well as attracting the attention of Air Force Chief Scientist Dr. Mark Maybury. "Her work is important for a couple of reasons," Maybury said. "She had a good understanding of not only the basic science that

was happening and the practical methods, but she also had a very insightful perspective on how she could improve existing practices. That's what's really extraordinary."

C1C Gingras' work on the Spice project has also laid the groundwork for additional research in the Department. For example, she has leveraged her experience with Spice identification to develop a capstone research project involving the use of fluorescent proteins as sensors to detect the presence of illegal drugs in a person's system.

Gingras' biochemistry instructor, Dr. Barry Hicks, praised Gingras' work ethic and enthusiasm.

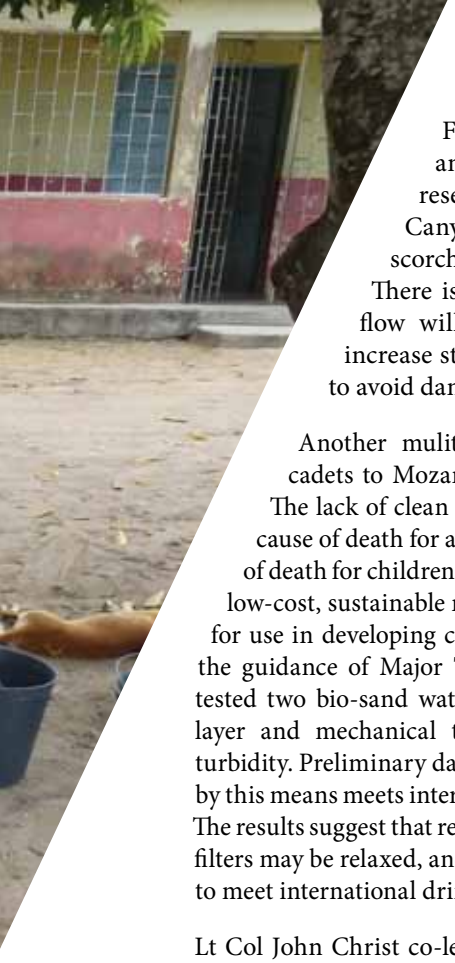
"After the election in November, when Colorado passed Amendment 64…I said, kind of flippantly, 'I wonder if drugs of abuse can be used in this sensing application.' She said, right off the bat, 'I want to pursue that. I want to do this,'" Hicks recalled.

Possible applications of Gingras' research could include portable drug-testing kits for military and civil law-enforcement agencies and breathalyzer tests for marijuana, Hicks said.

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Civil engineering encompasses the design, construction, and maintenance of the constructed and natural environment, including roads, bridges, airfields, dams, and buildings. Environmental engineering integrates science and engineering principles to improve the natural environment (air, water, and/or land), providing healthy water, air, and land for habitation by humans and other organisms, and to remediate pollution. The research efforts in the Academy's Department of Civil and Environmental Engineering (DFCE) focus on the current challenges faced by these engineering disciplines, including infrastructure protection, characterizing polluted ground and ground water and energy conservation (including sustainable buildings). In addition there is a substantive engineering education research effort.

"Through research, our faculty model both lifelong learning and service to the profession through generating new knowledge for our students." said DFCE Permanment Professor and Head, Colonel Gregory Seely. Cadets are research partners in technical subject areas (or conduct their own research), and publish results with faculty mentors.



For example, C1C Brett Brunner and Dr. Stanley Rader conducted research on the impact of the Waldo Canyon Fire on storm runoff from the scorched Camp Creek drainage basin. There is consensus that the storm water flow will increase dramatically, but the increase still needs to be estimated in order to avoid damage due to downstream flooding.

Another mulit-disciplinary DFCE project sent cadets to Mozambique during the spring of 2013. The lack of clean drinking water is the fifth leading cause of death for adults and the second leading cause of death for children under the age of five world-wide. A low-cost, sustainable means of purifying drinking water for use in developing countries is being developed under the guidance of Major Timothy Frank. Cadets built and tested two bio-sand water filters that employ a biological layer and mechanical trapping to reduce bacteria and turbidity. Preliminary data demonstrated that water filtered by this means meets international drinking water standards. The results suggest that requirements for these types of water filters may be relaxed, and disinfection may not be required to meet international drinking water standards.

Lt Col John Christ co-led a project in collaboration with Tufts University on protocol development for characterizing dense non-aqueous phase liquid (DNAPL)—a significant DoD contaminant—source zone architecture and plume response below the ground surface. This research is sponsored by the Strategic Environmental Research and Development Program (SERDP).

Lt Col Christ and his students participated in other SERDP-sponsored projects, as well. Collaborating with the Colorado School of Mines, his group focused on subsurface contaminant vapor (volatile organic compounds, or VOCs) transport. These contaminants sometimes make their way into interior building spaces, and this research will help assess contaminant risk to infrastructure and inform remediation strategies. Another SERDP project, conducted in partnership with Tufts University, is developing protocol(s) to test bioremediation for the purposes of treating subsurface chlorinated solvents that pose health risks.

Making the DoD's energy supply secure and reliable is a critical concern. Hence, USAFA conducts research on renewable energy and energy conserving technologies. One of these emerging technologies—energy foundations—combine the structural supports for a building with a ground source heat pump to provide a highly efficient heat source and sink. The foundations and ground serve to generate considerable energy savings related to the heating and cooling of buildings. Dr. Karen Henry and the University of Colorado-Boulder researcher, Dr. John McCartney, are generating data needed nationally and internationally on the performance of energy foundations to reduce energy

costs and carbon emissions from buildings. As part of this research, energy foundations were constructed for a new shower facility at the Field Engineering Readiness Laboratory (FERL) site in Jack's Valley in 2012. Cadet research includes long-term monitoring of the system's performance with respect to energy and fuel use, as well as a comparison of measured performance indicators including construction and life-cycle costs with those expected for conventional building heating and cooling systems. The DoD's Environmental Security Technology Certification Program (ESTCP) sponsors this work.

To reduce construction costs and related waste, Lt Col Patrick Suermann and Capt Lindsey Maddox worked with the US Army Corps of Engineers and the Air Force Civil Engineer Center (AFCEC) to evaluate efficiencies in building construction by utilizing Building Information Management (BIM) during design. It is hypothesized that the use of BIM during building design and construction project management results in the minimization of construction costs and time.

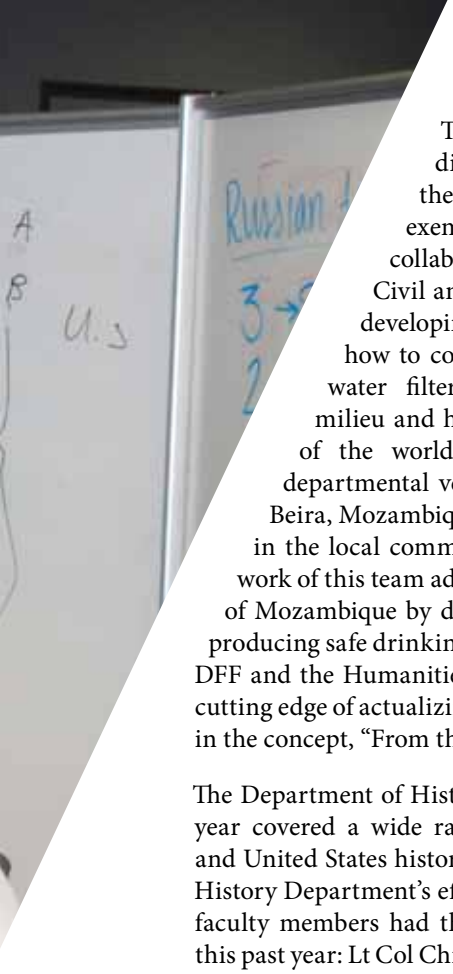
DFCE's engineering education research efforts continue to grow. The department has partnered with the Academy's Scholarship of Teaching and Learning (SoTL) on joint projects such as the exploration of the influence of learning contracts on student commitment and academic performance and on exploring the effectiveness of multi-disciplinary instruction and research on students' learning. Another project, led by Dr. Thomas Phelan and Capt Joseph Sundy, studied the educational effectiveness of using video clip tutorials to reinforce the fundamentals of engineering course material and model the solution of problems related to that particular topic. The tutorials can be downloaded from the course's website, and cadets may access them at any time when attempting to complete homework. Both the learning contracts research and the video tutorial work research and benefits were made available to other faculty at USAFA through USAFA's Center for Educational Excellence.

"All of our research efforts help the cadets learn how to solve complex problems locally, for the DoD, the nation and around the world," said Col Seely.

DIVISION OF HUMANITIES

At USAFA, the Humanities Division consists of English and Fine Arts (DFENG), Foreign Languages (DFF), History (DFH), Military and Strategic Studies (DFMI), and Philosophy (DFPY). Research in the Humanities division is about encouraging innovative, interdisciplinary collaboration and teaching. The Humanities rely on both qualitative and quantitative sources as appropriate to nurture officers of character to serve as air and space leaders in today's Air Force.

The Department of English and Fine Arts produced a strong number of research publications and presentations this year. Professor Donald Anderson's book *Gathering Noise from My Life: A Camouflaged Memoir* was published by the University of Iowa Press. Department faculty members also published a chapter in an edited volume, several stories and pieces of creative non-fiction, and a number of poems. DFENG faculty also secured nearly $18,000 in USAFA research grants for five different projects that will support advances in research and enhance teaching in the classroom. With a strong commitment to supporting and partnering with cadets in research, DFENG and the Center of Innovation supported a cadet working with the Intel Corporation in Hillsborough, Oregon, and also supported thirteen cadets presenting research at the Colorado Springs Undergraduate Research Forum (CSURF), where they presented research papers they wrote for courses under DFENG faculty mentorship.



The Division's collaboration across disciplines and cultures involving the work of both faculty and cadets is exemplified in Mrs. Alice Meyer's (DFF) collaboration with the Department of Civil and Environmental Engineering in developing a course where cadets learned how to construct and maintain a bio-sand water filter while exploring the cultural milieu and humanitarian need in other parts of the world. This multi-disciplinary, inter-departmental venture resulted in a cadet trip to Beira, Mozambique to train and educate 21 leaders in the local community about bio-sand filters. The work of this team addressed a basic need of the people of Mozambique by devising a sustainable solution for producing safe drinking water. It is a key example of how DFF and the Humanities Division as a whole are on the cutting edge of actualizing an educational model captured in the concept, "From the classroom to the field."

The Department of History faculty publications this past year covered a wide range of topics in world, military, and United States history that directly contributed to the History Department's effectiveness in the classroom. Two faculty members had their book manuscripts published this past year: Lt Col Christopher Rein's *The North African Air Campaign: U. S. Army Air Forces from El Alamein to Salerno,* and Dr. Jabob Abadi's *Tunisia Since the Arab Conquest: The Saga of a Westernized Muslim State*. Other members of DFH published twenty-three peer-reviewed journal and encyclopedia articles, while they also submitted fifteen book reviews to various journals. Two DFH cadets used their finely-honed research skills for real world applications that emphasize airpower's heritage by creating a living history exhibit at the National Weapons Instructional Museum (NWIM); this exhibit continues to be a benchmark of the NWIM, and a vital element of the Defense Nuclear Weapons School.

The Department of Military and Strategic Studies operates the Cadet Battle Lab (CBL), a state-of-the-art laboratory capable of closely replicating multiple real-world strategic environments. Cadets conduct research with users as diverse as the Defense Advanced Research Projects Agency, Central Intelligence Agency, the Department of Homeland Security, and the Intel Corporation. Cadets study ill-defined problems and work as diverse teams in conventional and irregular warfare environments. Recently, DFMI hosted the Joint Engagement Exercise (JENEX) in the CBL. Military & Strategic Studies majors C1C Carlos Berreteaga and C1C Tim Mobley created JENEX to fulfill their MSS Capstone requirements. JENEX engaged participants in a multitude of scenarios utilizing the AIR/SEA BATTLE concept in the Asia-Pacific Region. A realistic strategic simulation, JENEX participants overcame other teams' countering goals and restrictions, red forces, and the friction ultimately created by simulation control. In addition to Academy cadets, there were approximately 70 peer undergraduate students from local universities and sister service academies.

DFPY's faculty presented papers nationally and internationally, often by invitation from institutions such as the University of Pennsylvania Law School and the University of Oxford. The department's expertise in military ethics was in special demand, but faculty also spoke and published on hermeneutics, philosophy of language, philosophy of religion, ethics in science fiction, Plato, and rule consequentialism. Two cadets received department sponsorship to work at the Intel Corporation thanks to their philosophical education in critical thinking and logic. The Reich and McDermott Lectures featured speakers from the UK and the University of Wisconsin. Besides the lectures themselves, colloquia and other discussion fora associated with the lecture series included participants from several USAFA departments and Colorado College. DFPY served as co-chair of the National Character and Leadership Symposium's Scholars Forum. This year's Forum focused on professional military ethics, allowing DFPY to invite military ethicists from West Point, the Army Command and General Staff College, the Marine Corps University, and the Naval War College to address cadets, faculty, and guests.

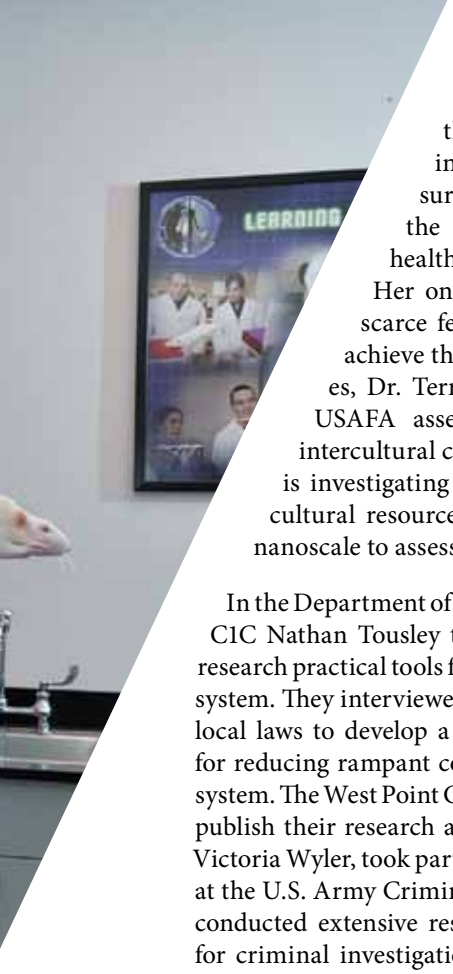
Through an expansive and robust research and teaching program extending beyond the confines of the humanities and the Academy, the Division is truly setting the pace for scientifically rooted, liberal education.

DIVISION OF SOCIAL SCIENCES

Research is a critical component of every cadet's experience at the Air Force Academy. As such, the Social Sciences Division strives to challenge cadets to maximize their learning through wide-ranging human subject and other research opportunities.

Each of the departments in the Social Science Division contributes to the diverse research spectrum at USAFA. One of the keystone research efforts during the 2012–2013 Academic Year (AY) in the Department of Behavioral Sciences & Leadership (DFBL) was the initial work towards the establishment of the Warfighter Effectiveness Research Center (WERC). Under the direction of Lt Col Douglas Lindsay, in collaboration with the Human Effectiveness Directorate and the 711th Human Performance Wing, funding for the next two years was secured to start up the center. The purpose of the WERC is to act as an in-department clearing house to assist DFBL faculty and cadets in securing funding for, conducting, and publishing their research. The center is already making an impact. During the 2012–2013 AY, a total of 27 cadets enrolled in Independent Research efforts with faculty in DFBL. Of these, C1C Rebecca Breslow's project, "A Proposed Influence Campaign to Reduce Honor Killings in Middle East," received special recognition by the U.S. Special Operations Command (USSOCOM), MacDill Air Force Base, Florida.

The Department of Economics and Geosciences faculty and cadets conducted applied and theoretical research on a variety of issues, including an Air Force-sponsored econometric study of the impact of the $232 million Selective Reenlistment Bonus (SRB) program on Airmen reenlistment decisions and retention. Dr. Kate Silz-Carson's research, funded in part by



the National Science Foundation, investigated the sources of bias in survey mechanisms used to estimate the benefits from environmental, health, and transportation programs. Her on-going research will help ensure scarce federal dollars for these programs achieve the greatest effect. In the Geosciences, Dr. Terry Haverluk's research is helping USAFA assess our cadets' development of intercultural competence, and Dr. Steve Gordon is investigating the state of decay of rock art at cultural resource sites and the use of GIS at the nanoscale to assess chemical decay.

In the Department of Law, Capt Jonathan Compton and C1C Nathan Tousley traveled to Monrovia, Liberia, to research practical tools for improving the Liberian judicial system. They interviewed Liberian leaders and researched local laws to develop a comprehensive recommendation for reducing rampant corruption in the Liberian judicial system. The West Point Center for the Rule of Law will soon publish their research as part of a five-year project. C1C Victoria Wyler, took part in an intensive research program at the U.S. Army Criminal Investigations Laboratory. She conducted extensive research on the laboratory's policy for criminal investigations of child pornography, which currently requires examiners to conduct a forensic review of every piece of evidence submitted by the government. Cadet Wyler's research demonstrated that this forensic requirement did not correlate to judicial outcomes in criminal prosecutions.

Leading complex systems has been the research theme in the Management Department (DFM). These systems are large and small, local and global. DFM continues to assist the Colorado Springs Police Department as our cadets completed a project entitled "Risk Terrain Modeling," combining statistical modeling with graphical mapping to highlight crime "hotspots." Cadets majoring in management also worked with Pentagon planners, evaluating alternatives for cost-effective acquisition of munitions using lot sizing – and earning the Social Sciences Division's top research award for cadets. Cadets involved in the Department's Technology Innovation capstone experience explored the science of algae growth and protecting boat hulls with an environmentally-friendly polymer process.

Research in the Department of Political Science (DFPS) fosters enhanced cadet learning opportunities and promotes faculty professional development in a broad variety of ways. Political Science majors have the opportunity to intern in the offices of members of Congress, participate in faculty-led research trips in other countries, and interact with future civilian leaders of their own generation through the ALLIES program (Alliance Linking Leaders in Education and the Services).

Each of these initiatives demonstrates the benefits research provides to enhancing cadet education and sustaining faculty development while at the same time contributing new thinking to policy makers on security questions of interest in the 21st century world our graduates will enter as Air Force leaders.

EISENHOWER CENTER FOR SPACE AND DEFENSE STUDIES

The Eisenhower Center for Space and Defense Studies is the research center for the Department of Political Science, providing a focus for faculty and cadets in the field of defense and security studies, which has been a tradition in the Department for fifty years. The Center works to create opportunities to bring cadets and faculty members together with policy makers and contribute new ideas to improve the understanding and analysis of emerging challenges in the 21st Century. Through first-hand exposure to national and international leaders in workshops and discussions organized by the Eisenhower Center, cadets learn directly from leading experts about the issues and problems that will confront them in their Air Force careers. In particular, the Center also engages cadets who are neither from engineering or science degree programs nor destined for assignment in the space and missile career field. In so doing, the Eisenhower Center increases the number of Academy graduates with a greater depth of understanding of the security and policy issues in the space and cyber domains and how these play in overall U.S. defense and strategic policy, contributing not only to enhancing military capability but also to achieving overall U.S. foreign and strategic policy goals.

Led by Ambassador Roger Harrison, over the past seven years the Eisenhower Center has greatly increased the resources the Academy devotes to space and security studies, including the publication of its Space Defense Policy textbook, expansion of graduate study opportunities in space policy for cadets, funding cadet and faculty research projects and internships, and bringing cadets together with senior officials and other experts in workshops on key

space policy issues facing the United States. These workshops have included a series of discussions on topics ranging from improving space situational awareness, trans-Atlantic space cooperation, and the dynamics of US-Chinese strategy and security in space.

Building on this past experience, US-China relations has become an area of increased interest for the Eisenhower Center. This past year the Center has hosted two Minerva Research Chairs, sponsored through a grant from the Office of the Secretary of Defense. Dr. Fei-Ling "Phil" Wang from the Nunn School at the Georgia Institute of Technology is working on a book-length project on Chinese grand strategy, including case studies drawn from the African continent and the Middle East. Dr. Charlotte Lee from Hamilton College is completing a book manuscript on party adaptation in China, with a particular focus on the Chinese Communist Party's system of training academies for party members. In addition to conducting their individual research, both Minerva Chairs have taught classes in the Political Science Department, worked with cadets and faculty on papers and topics of mutual interests, and been invited participants in academic conferences and workshops across the country. Both Dr. Wang and Dr. Lee served as roundtable leaders for the annual Air Force Academy Assembly which was focused this year on US-China relations, bringing students to USAFA from top-tier civilian universities across the nation.

In November 2012, Ambassador Roger Harrison (DFPS) and both Minerva Chairs led a USAFA delegation including C1C Deanna MacMillan and C1C Nate Youd to participate in the international workshop "Leadership Change and Strategic Opportunities: U.S.-China Relations and the 18th Chinese Communist Party Congress." cosponsored by the Carter Presidential Center of Emory University, the DOD Minerva Initiative and the University of Chicago. This workshop was attended by more than two dozen scholars, officials, and journalists from China and the United States.

The Eisenhower Center is also currently working on a study of "cross-domain" deterrence for the Office of the Secretary of Defense, examining the role of deterrence as applied to both the space and cyber domains. This study follows on the success of the Center's earlier studies for OSD on space deterrence, governance, and verification.

The Center is named in honor of Dwight D. Eisenhower. Eisenhower was the first American president to establish a national policy on the use of space for both military and civilian purposes. His legacy—the creation of both the National Reconnaissance Office and NASA—laid the foundation for the manned space program, the use of space to bolster national security, and the infrastructure which led to revolutions in battle management and global communications. This foundation remains the benchmark against which all successive policies are measured.

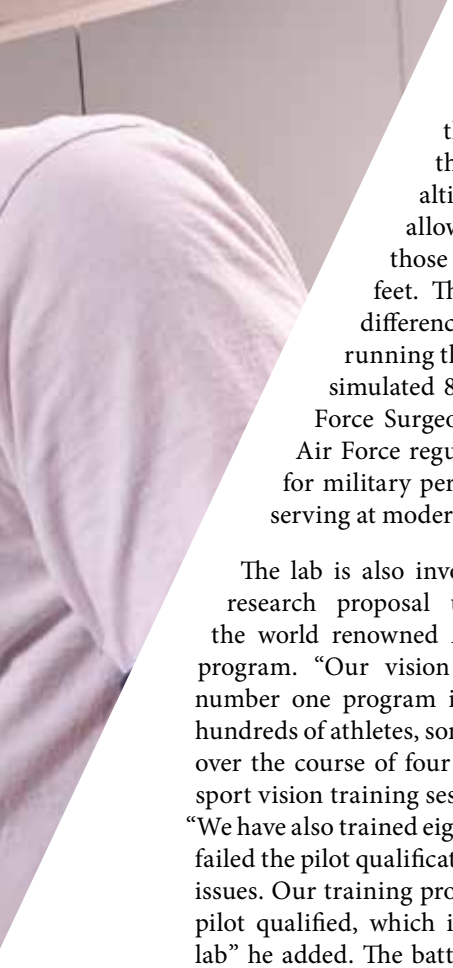
"When we think about space, we tend to think about it technically. We need to think about it politically and strategically. The space domain confronts the war fighter with distinct challenges, both operationally and in terms of policy. The Center's task is to prepare them for those challenges, giving them the opportunity for cutting edge research and to nurture them as future leaders of the greatest aerospace force in the world," said Harrison.

HUMAN PERFORMANCE LABORATORY

The United States Air Force Academy athletic department's Human Performance Laboratory (HPL) has been involved with a myriad of research initiatives relative to athletic performance in the past twenty years.

"Athletic Director, Dr. Hans Mueh, has given lab director, Lt. Col. Michael Zupan, and his staff full support to continue research in the athletic department utilizing not only our cadet population but our visiting interns as well," said assistant Human Performance Laboratory director Coach Al Wile. Recent research in altitude acclimatization, altitude performance and enhancement, as well as vision enhancement and performance in sports has resulted in numerous research journal articles and published longitudinal studies. These research protocols have directly affected Air Force military personnel and contributed to further research in all branches of the service in regard to acclimatization and performance of military personnel throughout the world.

Last year, the HPL conducted a study on the effects of altitude on personnel completing the annual one and a half mile run. The study utilized the state of the art Colorado hypoxic tent, which allows the athletes to be tested in the mile and a half run at altitude and sea level. This can be done with the hypoxic tent by simulating the oxygen levels at sea level to 15,000 feet through the production of oxygen reduced air. The tent creates a hypoxic environment inside with an air separation unit (oxygen and nitrogen) that continually pumps low oxygen content air into the tent. Inside the tent the total pressure stays the same but the percent oxygen content air can be reduced; thus, the partial pressure of oxygen is reduced. This study benefited



the Air Force personnel who took the annual fitness test at moderate altitude. Prior to 2010, the Air Force allowed small altitude adjustment for those airmen stationed above 5,000 feet. The study illustrated a significant difference in times of the 55 subjects each running the mile and a half at 7,200 feet and simulated 850 feet. These results led the Air Force Surgeon General's office to change the Air Force regulation to allow time adjustments for military personnel throughout the Air Force serving at moderate altitude.

The lab is also involved with a pioneer battlevision research proposal utilizing training principles of the world renowned Air Force Academy sport vision program. "Our vision program is recognized as the number one program in the world as we have trained hundreds of athletes, some with over 150 training sessions over the course of four years. "We have seen over 2,000 sport vision training sessions a year in the lab," said Wile. "We have also trained eight cadets in the past two years that failed the pilot qualification exam due to depth perception issues. Our training protocol enabled all eight to become pilot qualified, which is pretty gratifying for us in the lab" he added. The battlevision research involved 60 Air Force Security Forces personnel. The subjects were given a pre-test with several sport vision protocols involving eye-hand coordination with the Dynavision D2 Board, accommodation/convergence, depth perception, saccadic eye movements, tachistoscope (speed recognition), and eye tracking. Following the pre-test, the subjects were given an M-4 rifle pre-test with pop-up targets on a firing range trail along with a pre-test on an improvised explosive device (IED) lane as they rode gun mount of a Humvee vehicle and identify IEDs while traveling 10 miles per hour. Following this, 30 of the subjects then received battlevision training for a six week period while the other thirty subjects did not. A post-test was then conducted in the vision lab as well as the IED lane and rifle lane. Results showed substantial differences (as much as 16% improvement) in scores of the post test results with those receiving the training doing significantly better, especially on the firing range.

Researchers in the HPL are also working on a sports vision protocol, which will utilize the Dynavision D2 eye hand coordination device. The purpose of the study is "to determine if vision training can enhance the efficiency and effectiveness of eye-hand coordination and to determine if the trained effect will diminish after a number of weeks layoff," stated Wile. The study will involve a pre-test on eye-hand speed of twenty cadets using the Dynavision D2. The cadets will then undergo a seventeen-week training protocol with the D2. Upon completion of the seventeen weeks of training, a retention-test will be conducted three weeks later to measure results and determine whether a three-week layoff will alter the results of the post-test.

"The opportunity for research in the Human Performance Laboratory is an avenue for us to not only provide opportunities to our cadets and to further enhance human performance in all realms of athletic performance, but to allow us to continue to be the pioneers of acclimatization research and sports vision training throughout the world," Wile concluded.

INSTITUTE FOR INFORMATION TECHNOLOGY APPLICATIONS

The Institute for Information Technology Applications (IITA) is an Air Force research institute comprised of multiple independent research groups, directed by retired USAF General James P. McCarthy. According to General McCarthy, "when budgets get lean, we need to focus our research efforts and deliver smart technology innovations to continue to meet the Air Force and Department of Defense missions." IITA's vision is to serve as a renowned Air Force research center for operational and educational information technology applications. Several projects have been highly successful in providing new capabilities and increasing productivity, thereby winning Air Force- and DoD-wide attention.

One of IITA's long term research programs, the Airdrop Enhanced Logistics Visibility Information System (AELVIS) Program blends multiple technologies to provide airdrop bundle situational awareness data to warfighters. In 2012, AELVIS was included in the Air Mobility Command—Air Force Research Laboratory (AMC-AFRL) Precision Airdrop Flagship Capability Concept baseline and was singled out by the AMC Commander as a "MacGyver" solution for warfighters. The AELVIS software was accredited for use on both classified and unclassified networks and achieved a successful end-to-end test through the Iridium and UHF SATCOM constellations into ruggedized field equipment. The AELVIS research team is working to field this technology for operational testing at several AMC C-130 and C-17 bases.

The Institute has a long history of shepherding game-changing training and technologies at the Academy and more broadly, in the USAF mission. The Unmanned Aerial Systems—Remotely Piloted Aircraft Program (UAS-RPA), is one such program.

Directed by Col John McCurdy, the program has made great progress over the past year to build future combat Air Power leadership in a realistic combat training environment. In its fourth cadet-run year, 48 cadet instructors trained over 200 underclassmen. McCurdy continues to expand opportunities for cadets to gain air power employment experience and exposure to cutting edge technologies. The program acquired new MQ-11 Raven UAS platforms to provide support to multiple USAFA mission elements, and cadets attended formal training on these platforms at Hurlburt Field. In the coming year, the program is pursuing the creation of an Integrated Warfare Laboratory. Col McCurdy's vision is to create a facility where cadets can experience the best of what technology has to offer air battle management. According to Col McCurdy, "The goal is to create an environment that will introduce these future officers to how we operate in the battlespace above. I want to equip them with the vision to become innovative airpower leaders for tomorrow's Air Force."

The IITA's largest program, Warfighter's Edge (WEdge), continues innovating to break down stovepipes and move actionable information to the warfighter. Last year, the program created WEdgeNET, a secure application that replaces antiquated emails and faxes with a secure, cloud-like capability, certified for classified networks. WEdgeNET is viewed as the foundation for secure, seamless information sharing in distributed mission planning applications. The team also developed a visionary system to automate the AMC's digital flight binder system. The WEdge Digital Binder replaces a staff that manually gathers flight planning data for AMC air crews with an automated capability that will save AMC over 8,000 man hours per year. Looking to the future, the next generation of the WEdge Shuttle is due to be released in October of 2013. Shuttle 2.0 will implement new features to allow geographically separated warfighters to share massive video and other files, ultimately extending RPA intelligence and operations data to the broader operational community.

The Geospatial Technology Center (GTC) continues to build on its rich history that includes the development of GeoBase and a portable Google Earth server. Last year, the center completed a project that successfully delivered several Google Earth Servers to AMC and supporting the intelligence and operations communities. Initiated as a technology development program, the Google Earth portable globe production mission has been successfully transitioned to the National Geospatial Intelligence Agency and is now supporting all of DoD. The geospatial data system established here at USAFA by the GTC will support cadet education in the Economics and Geosciences Department.

The Wing IT Services Engineers (WISE) team takes a hands-on approach to working with cadets. This technology

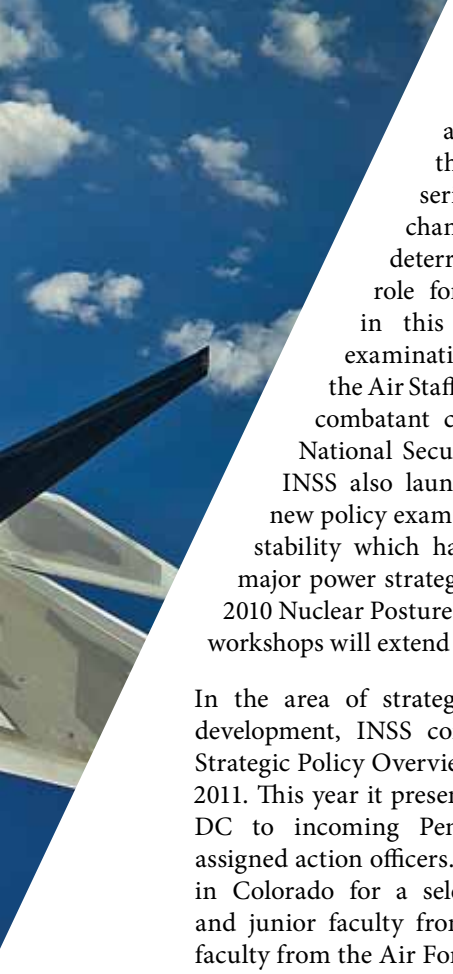
leadership lab for the Wing Communications Officer and cadets is operated by Ms. Carolyn Dull. Dull and the WISE team mentors cadets as they tackle real-world information technology challenges affecting the USAFA mission. For example, C1C Benjamin Baumann and C1C Benjamin Kram solved the longstanding problem of overflowing packages in the cadet mailroom by creating an automated and streamlined cadet postal package delivery notification system. The WISE cadets learned the intricacies of software maintenance as they assumed full production support for the Vehicle Registration and Parking Management System, developed by previous WISE cadets. The mobile application started last year completed a proof of concept demonstration and is poised for an implementation study. The cadets also addressed some key concerns from Academy leaders regarding cadet accountability by integrating Global Positioning System inputs in the iOS app. The WISE cadets continue to target ambitious projects, planning to examine thin client applications and technologies to securely "bring your own device" to advance portability and accessibility in the cadet IT world.

NATIONAL INSTITUTE FOR SECURITY STUDIES

The Air Force Institute for National Security Studies (INSS) has sponsored research, published reports, and developed leaders with strategic knowledge and perspective for over 20 years. Today it is well-positioned to continue to support Air Force interests in enduring and emerging strategic security issues. Housed within the faculty at USAFA, INSS reaches out across the USAFA faculty and the broader military academic community to conduct research and to bridge the civilian and government policy communities on strategic issues. Faced with reduced resources for academic year 2012-2013, INSS was still able to maintain a significant focus in each of its three mission areas: strategic policy research, strategic leader development, and strategic outreach and publication.

This year INSS sponsored 21 research projects investigating issues related to enduring and emerging security issues, with special focus on strategic stability, deterrence, and arms control issues, as well as on issues surrounding implementation of the new United States defense strategy. INSS researchers ranged from the military academic community, including USAFA, USMA, National Defense University, Air War College, and Marshall Center faculties plus Air Force Institute of Technology PhD students, to Air Force and Army officers serving in policy positions in the field. INSS distributes these research products to interested USAF and DoD offices and arranges briefings by the researchers upon request.

In addition to these projects, INSS arranges and hosts small, interactive policy analysis workshops where expert presenters and audiences together examine emerging and ill-defined issues toward the identification and development of options



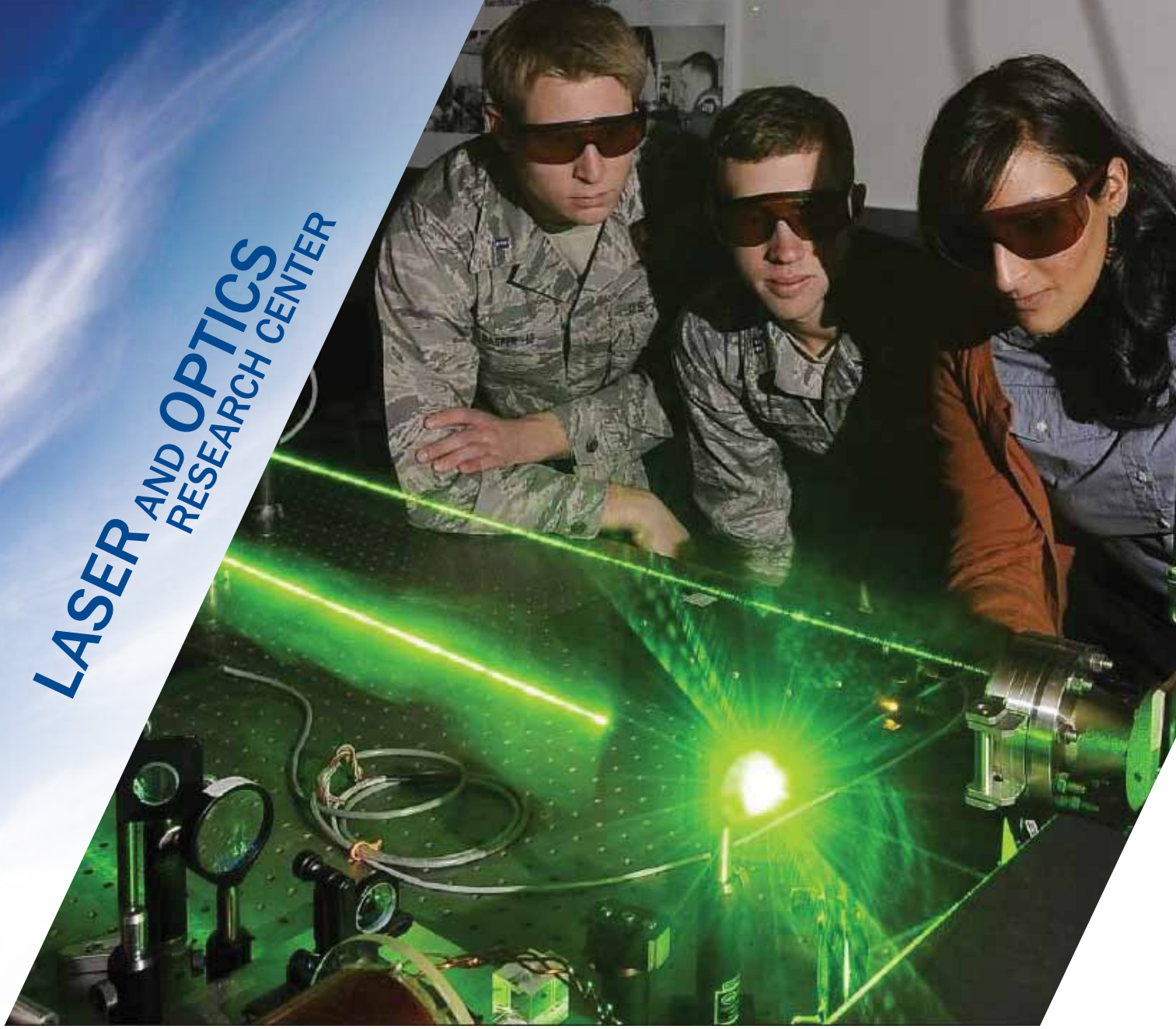
and courses of action. This year the Institute completed a three-year series of workshops examining the changing requirements of extended deterrence and especially the increasing role for USAF personnel and systems in this important policy arena. This examination involved several offices from the Air Staff, the Joint and DoD staffs, selected combatant commands and NATO, and the National Security Staff from the White House. INSS also launched the first two phases of its new policy examination of the concept of strategic stability which has been recast and is central to major power strategic relationships as defined in the 2010 Nuclear Posture Review. This series of studies and workshops will extend into AY 2013-2014.

In the area of strategic policy education and leader development, INSS continued its presentation of the Strategic Policy Overview program that it first offered in 2011. This year it presented the program in Washington DC to incoming Pentagon and USAF interagency-assigned action officers. INSS then repeated the program in Colorado for a select group of graduate students and junior faculty from across the country, including faculty from the Air Force Academy and the US Military Academy. The program was presented a third time at the invitation of HQ USAF Global Strike Command at Barksdale AFB, Louisiana.

The third INSS mission pillar, strategic outreach and publication, is represented by both internal and external contributions and publications. INSS e-published four Research Papers, two Strategic Papers (one by a member of the INSS staff), and one Occasional Paper. INSS also published the Occasional Paper in hard copy, and members of the Institute staff contributed across the process through which that study was developed. INSS also wrote and published the five Workshop Reports and Series Report from the extended deterrence series in paper and electronic versions. In addition, INSS staff had chapters published in edited texts by major university press outlets, one in distribution this year and two in the publication pipeline. The INSS staff also has two new Occasional Papers in preparation as well as a textbook revision in development. Our staff expertise was recognized by requests from major publishers that we review and make publication recommendations on two book manuscripts and a journal article.

In a changing and challenging policy research environment, INSS is adapting and continuing to provide its unique and cost-effective policy analysis to the USAF strategic community, with enduring benefits to the USAFA faculty and through it to USAFA cadets.

LASER AND OPTICS RESEARCH CENTER



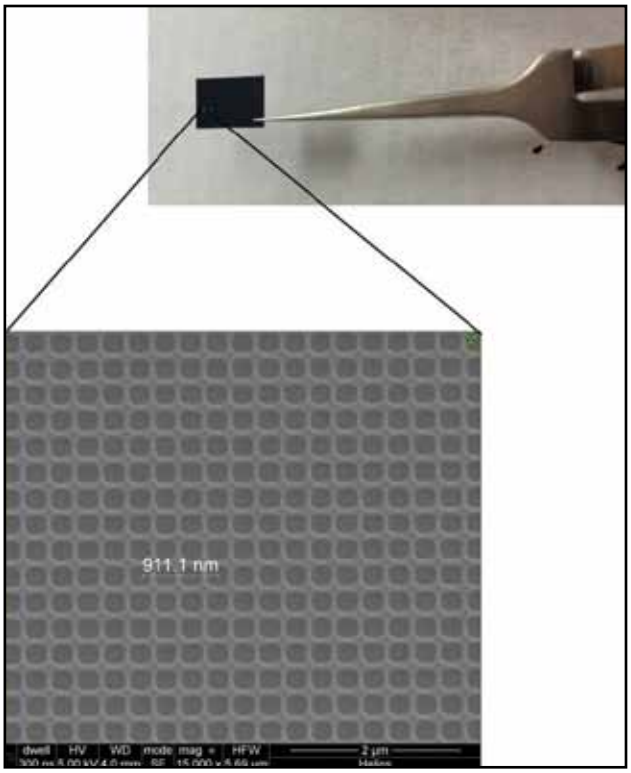
Directed energy and optical information technologies are undergoing rapid development and deployment, and the Academy's Laser and Optics Research Center (LORC) is leading the way in developing and understanding new lasers, optical devices, and materials. The LORC offers a unique environment where cadets and researchers can investigate and develop progressive ideas for the Air Force, Department of Defense (DoD) and industry partners.

The LORC is directed by Dr. Randy Knize and is supported with 12 fulltime researchers operating approximately $10M of advanced research equipment. The LORC offers cadets a unique opportunity to be mentored and perform research at one of the most well-funded undergraduate research labs in the nation. In 2012 the center was awarded $1.95M through competitive grants from agencies including the National Science Foundation (NSF), Air Force Office of Scientific Research (AFOSR), Air Force Research Laboratory (AFRL), Missile Defense Agency (MDA), High Energy Laser Joint Technology Office (HEL-JTO), and the Defense Advanced Research Projects Agency (DARPA) to perform research in fiber lasers, holographic and adaptive optics, alkali lasers, atomic physics, metamaterials, and nanotechnology.

Ongoing research in high power fiber lasers and amplifiers continued in the LORC in the 2012–2013 AY, culminating in a monolithic Erbium-only high power 1600-nm fiber laser. This laser achieved near record efficiency and is the only

monolithic laser of its kind that has ever been produced. Results will soon be published in several peer-reviewed publications. New funding was received this year for a HEL-JTO program on fiber laser engines, a joint program with the University of Central Florida and Optical Engines, Inc.

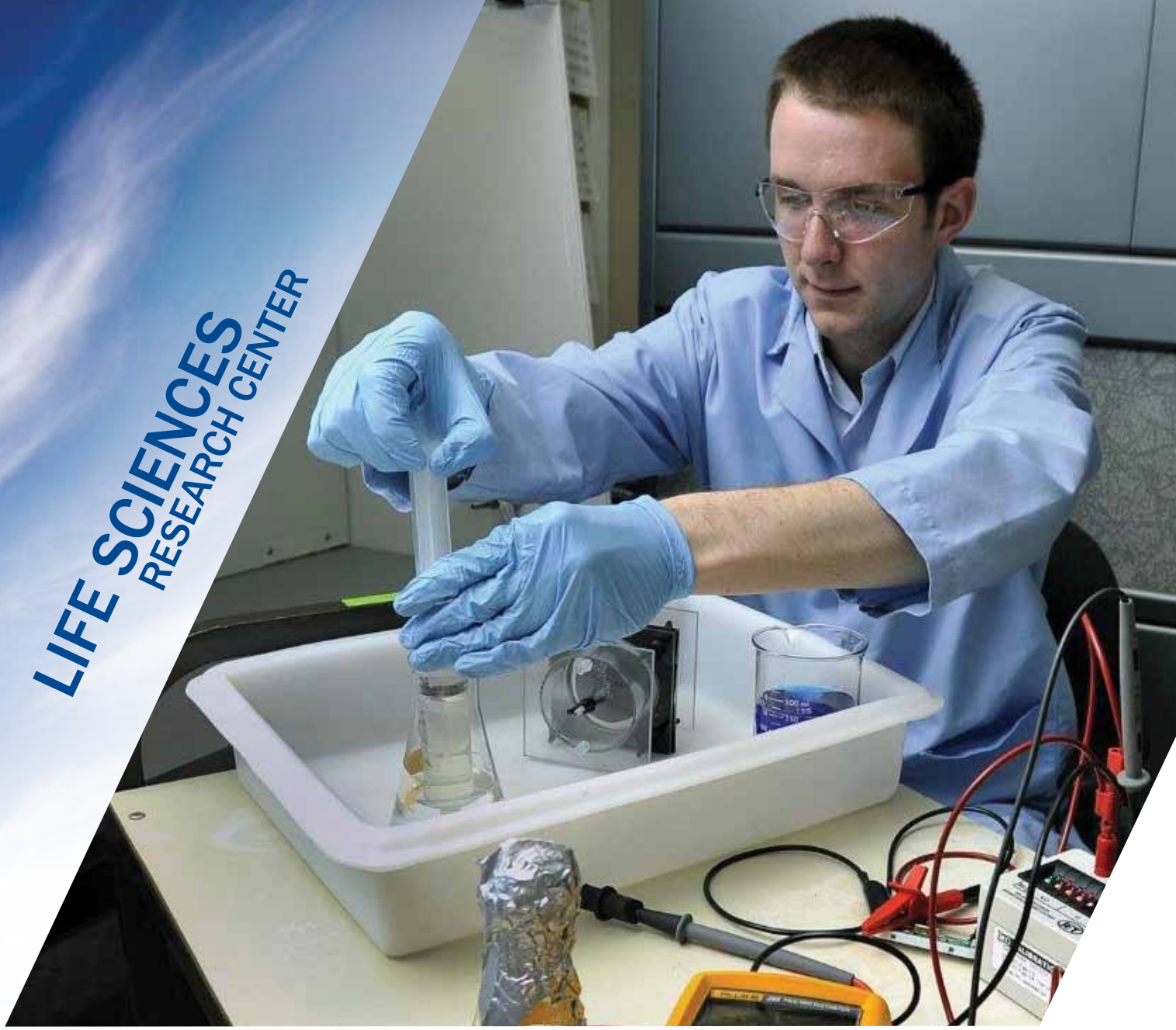
LORC researchers in large space optics, holographic optics, and wave front sensing, led by Dr. Geoff Andersen, developed a high speed and compact holographic adaptive optics system designed to remove distortions in optical beams. This technology has been developed into a table-top prototype that can correct for atmospheric aberrations to improve surveillance resolution. The feasibility of using this technology is also being investigated as a means to coherently combine multiple lasers for high energy laser applications. The LORC is also collaborating with the Space Physics and Atmospheric Research Center (SPARC) on the upcoming DARPA funded FalconSAT-7 mission to launch a space-based solar telescope. The LORC, along with C1C Rob Gasper, is designing and testing the novel membrane photon sieve primary lens, which will be the world's first demonstration of a collapsible lightweight optic. Metamaterials and nanotechnology research in the LORC includes three distinct efforts: Nanostructure-Enhanced Photon Conversion and Detection, Spectral Signature Modification, and Property Enhancement of Silicon. Dr. Yalin Lu conducted on-going research into the development of nanostructures embedded in materials to enhance their ability to sense/detect electromagnetic fields and temperature, or to convert energies among plasmons and phonons. Such nanostructures have potential to be highly tunable and integratable with emerging nanoelectronics and nanophotonics. In another project Dr. Jody Mandeville with Mitre Corporation investigated the spectral signature modification of non-planar surfaces for DoD applications through engineered materials that are commonly referred to as "metamaterials" or Engineered Electromagnetic Materials and Structures (EEMS). These materials allow for the design of specific characteristics including reflection, absorption, and transmission in a very thin layer. Both Mandeville's and Lu's projects extensively use many of the specialized advanced equipment in the LORC. Lastly, Dr. Rani Ayachitula and cadets C1Cs Robert Gasper, Matthew Matters, and Logan Brandt utilized lasers to ablate silicon in the presence of a chalcogenide Group 16 element (such as the sulfur in SF_6), thereby changing the optical properties of the silicon. Microstructures have been constructed on silicon wafers in this manner by shooting the wafers with pulses from a commercial Nd:YAG laser. This process yielded a 50% increase in the infrared absorption of silicon and a smaller increase in absorption over the 400-1600nm wavelength range. The results from these studies were submitted to the American Journal of Physics at the end of the semester and show promise to advance solar power production.



Since 2004, the LORC has been a world leader in alkali laser research and development and still holds many alkali laser performance records today. Led by Dr. Randy Knize, alkali laser research and development is progressing strongly, achieving laser power and efficiency milestones. Last semester C1Cs Logan Brant and Josh Hicks researched ionization in gain media and presented their findings at the Directed Energy Professional Society's annual symposium in Albuquerque in November 2012. The LORC will continue to investigate techniques to increase efficiency of narrowband high power diode laser sources, while actively involving cadet researchers in the excitement of scientific discovery.

In addition to applied physics, the center conducts research in basic atomic physics including experiments to precisely measure a variety of atomic structure properties. These experiments are possible thanks to the lab's many ultrafast (femtosecond) pulsed laser systems along with highly sensitive detectors. One of these experiments, investigated by Drs. Jerry Sell and Brian Patterson, seeks to measure the rate at which electrons flip their spin when interacting with different gases at various pressures. Although a fundamental study, the results of this experiment have implications in the design of alkali lasers and optical pumping of atoms. Sell and Patterson have observed and explained a unique three-body effect which was published with the help of cadets. Experiments measuring atomic lifetimes are in progress with funding from a new 3-year National Science Foundation (NSF) grant.

LIFE SCIENCES RESEARCH CENTER



Energy is both the problem and solution in today's US Air Force. There are a number of theoretical alternative energy sources but they require considerable research and investment to fully exploit. The cost of fueling a global force is driving many new innovations in energy across USAF installations world-wide. The Life Science Research Center (LSRC) is a part of that innovation effort.

The LSRC, led by Dr. Don Veverka, offers a wide-range of real-world research opportunities for cadets and is producing real-world results. One research area with real-world impacts was renewable energy. The 2012–2013 AY offered new opportunities, and recognition for previous efforts, in algae bio-fuels research and renewable energy producing photosynthetic organisms, also known as Microbial Fuel Cells (MFC).

Funded by the Air Force Office of Scientific Research, cadets studied the potential use of photosynthetic organisms in Microbial Fuel Cells (MFCs). These electrochemical organisms could potentially convert fuels substrates into clean bio-electrical power. Since they derive energy from the sun, harnessing this natural process could offer a variety of benefits including eliminating toxic energy waste, or producing chemicals for commercial uses. The lab is already testing a strain of cyanobacteria in a prototype MFC model for electrical current generation.

LSRC also worked with local high school student, Ms Sara Volz who provided LSRC with new data involving environmental manipulations of select algae for biofuels. Working with LSRC and in the Department of Chemistry with Dr. Timm Knoerzer, Ms Volz investigated ways of increasing the oil content of the algae, and thereby make it an economically viable source of biofuel. Her efforts won multiple accolades including a $50,000 Davidson Fellow Laureate college scholarship, early acceptance to MIT, and ultimately the top award of $100,000 at the Intel Science Talent Search.

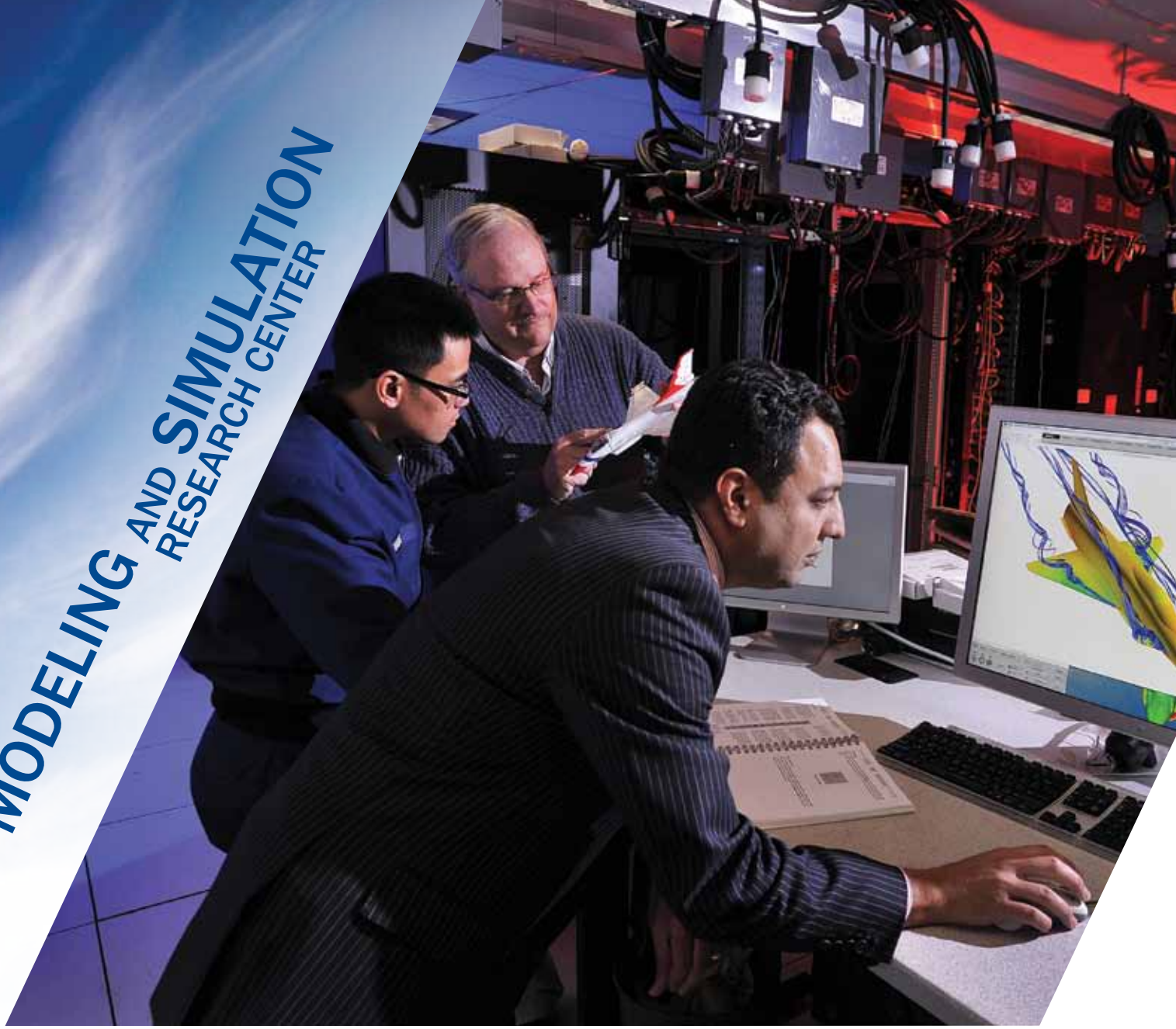
LSRC's Force Protection efforts also made considerable inroads this past year. Last year, LSRC tested a novel combination of master mix reagents for polymerase chain reaction (PCR). The mixes are novel because they remain stable in field conditions, unlike currently used reagents which typically require cold storage to extend usefulness and efficacy. Stable PCR reagents are needed because they allow real-time, and in-theater detection of biological threats (Anthrax for example). Seminal research on the PCR reagents by cadet C1C Craig Nowadly and C2C Jason David suggest certain reagents have an expanded range of usage that would extend biodetection capabilities far in excess of conventional thinking. Cadet Nowadly presented his data at a recent undergraduate research conference where he was singled out for "best conference presentation" and went on to present his work at a national conference held in Puerto Rico.

As is evident in the previous paragraph, Cadets remain the cornerstone of our research efforts. This year, LSRC had three cadets participate in summer research efforts at Tyndall AFB, FL and Wright-Patterson AFB, OH to work with scientists on various aspects of alternative energy research. Cadet Matt Webb investigated the feasibility of biogas production through use of biomass in an Anaerobic Digestion process. Cadet Webb used select algal-biomass samples in a pilot scale anaerobic digester, and demonstrated that the algal strains produced methane rich biogas. Cadet John Fonbuena, working side by-side with University of Dayton researchers, set up a pilot demonstration of CO_2 sequestration by using flue gas from a coal fire plant to supply CO_2 to algae ponds. Cadet Fonbuena's work focused on selecting and cultivating certain algal strains to optimize the uptake of the CO_2 gases from the power plant. Finally, Cadet Craig Nowadly worked with the Air Force Research Lab (AFRL) to quantify levels of bacteria in aviation and diesel fuels. Understanding the dynamics of microbial growth in fuels is essential to preventing microbial fuel contamination in aircraft. His research helped AFRL scientists determine appropriate concentrations of a jet fuel additive, diethylene glycol monomethyl ether (DiEGME), which inhibits the

growth of fuel-contaminating organisms. Without his help, AFRL's research would have been delayed. One AFRL staff scientist remarked, "Cadet Nowadly produced two excellent poster presentations and one written report about his summer research. Due to his singular outstanding research efforts, Cadet Nowadly's work will be published in a peer-reviewed publication (Journal of Industrial Biotechnology) in the near future."

While classroom education is vital in preparing young men and women for leadership positions within the Air Force, the Academy also appreciates that conducting research is paramount in further refining their leadership development….learning how to manage their time, money and other resources instrumental towards successful research. By dramatically expanding cadet and faculty research program opportunities beyond typical laboratory settings, we place our young leaders into "hands-on" research experiences, and thereby enrich the educational experiences of USAFA cadets and present yet another opportunity for faculty and cadets to work together to further USAF operational needs. Eventually these young men and women grow into senior leaders which eventually will make decisions about executing various research programs. "I value cadet research for several reasons. First, it simply offers a different way for cadets to learn biology. Second, research activities often captivate a sub-population of our cadets who are not as stimulated by the read & write learning style typical of class room study. Finally, cadet research engages and excites the instructors, too," said Col John Putnam, the Permanent Professor and Head of the Department of Biology.

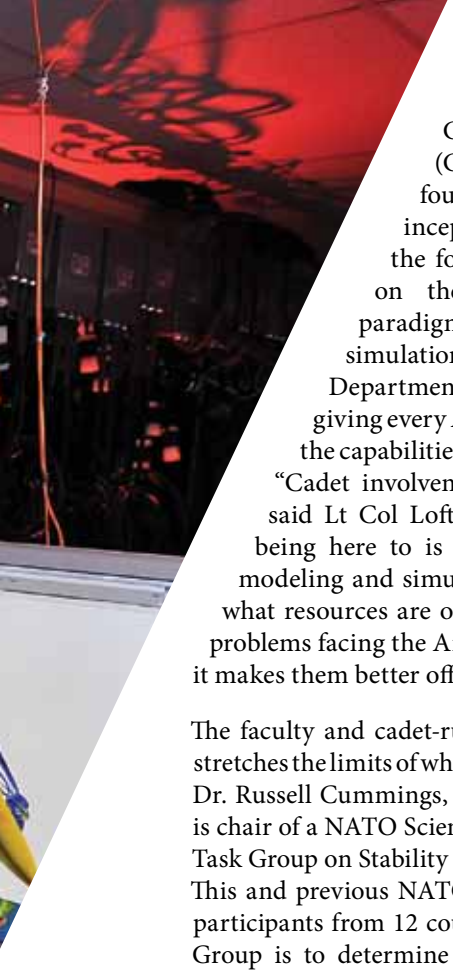
MODELING AND SIMULATION RESEARCH CENTER



Moore's Law essentially states that computer processing speeds double approximately every two years. The trend continues today through the use of massively parallel supercomputers. Some of the world's fastest supercomputers are owned and operated by the Department of Defense, the largest of which is located at the Air Force Research Laboratory (AFRL) at Wright-Patterson AFB, Ohio.

For the past 10 years, the Academy's Modeling and Simulation Research Center (MSRC) has created an environment that allows faculty and cadets to take advantage of computing performance increases to perform cutting-edge, defense-focused, modeling and simulation research. Whether it's the modest, in-house cluster of 144 computational cores or the nearly-75,000-computational-core supercomputer housed at AFRL, the MSRC provides access to the computational power needed to tackle science and engineering's largest, most complex problems.

The MSRC recently welcomed its newest director, Lt Col Andrew Lofthouse. From his past assignments on the faculty at the Air Force Institute of Technology and as Deputy Director of the Computational Sciences Center of Excellence at AFRL, Lt Col Lofthouse brings a wealth of experience in High Performance Computing that will now serve the USAFA community well. "I'm very excited to be here," he says. "If I could pick any assignment across the entire Air Force, this would be it."

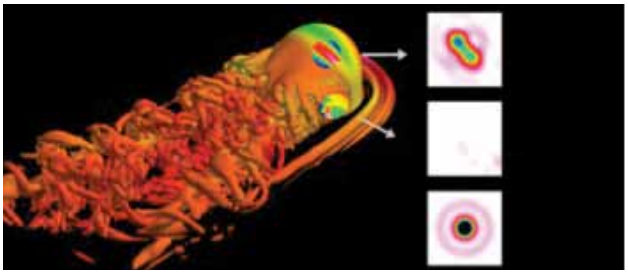


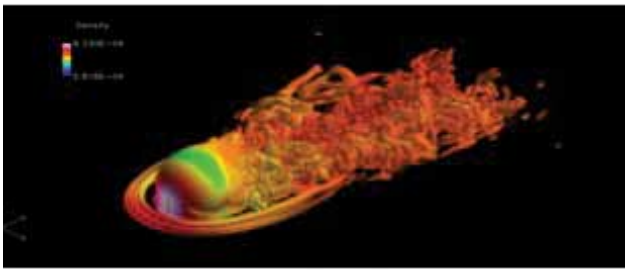
Computational Fluid Dynamics (CFD) work has been the foundation of the MSRC since its inception, and it continues to be at the forefront of the center's emphasis on the Academy's learning-focused paradigm. Computational modeling and simulation is integrated throughout the Department of Aeronautics curriculum, giving every Aeronautics cadet a foundation in the capabilities of computational aerodynamics. "Cadet involvement in our research is critical," said Lt Col Lofthouse. "Our whole purpose for being here to is to give cadets a foundation in modeling and simulation that will help them know what resources are out there for solving the complex problems facing the Air Force and the DoD. Ultimately, it makes them better officers."

The faculty and cadet-run research using CFD methods stretches the limits of what computational modeling can do. Dr. Russell Cummings, Research Director for the MSRC, is chair of a NATO Science and Technology Organization Task Group on Stability and Control Estimation Methods. This and previous NATO Task Groups have included 46 participants from 12 countries. The objective of the Task Group is to determine an overall strategy for creating stability and control databases for vehicle simulation at full-scale conditions, throughout the operational envelope of the vehicle using CFD. "This capability would significantly reduce the number of ground tests required to verify vehicle concepts and, in general, could eliminate costly vehicle 'repair' campaigns required to fix performance anomalies that were not adequately predicted prior to full-scale vehicle development," said Dr. Cummings. "The final result is significant reductions in acquisition cost, schedule and risk."

As part of the NATO Task Group work, C1C Krzysztof Ryszka analyzed the effect of blunt leading-edges on vortex-dominated, separated flows for delta wings. Vortices are the main source of lift on medium/high sweep delta wings at medium to high angles of attack at subsonic speeds. An understanding of the vortices shed from the leading edges is also required to accurately predict the pitching moment of the aircraft. C1C Ryszka's work increased understanding of this complex aerodynamic phenomena and could lead to better designed air-vehicles in the future.

Dr. Mehdi Ghoreyshi, a National Research Council post-doctoral fellow currently at the Academy working with the MSRC and the NATO Task Group, has developed methods for reduced-order-modeling of aircraft stability characteristics during complex maneuvers. Current CFD tools have recently become credible for modeling unsteady, nonlinear physics and can help reduce the amount of wind tunnel and flight testing required to determine full-scale aircraft aerodynamics. Complex CFD simulations are used to develop reduced-order models to predict aircraft





performance, including that of an Uninhabited Combat Air Vehicle undergoing a lazy-eight maneuver.

Under the tutelage of Drs. Chris Porter and Jürgen Seidel of the Aeronautics Research Center, C1C Ryan Petrie investigated the effect of the turbulent flow field around an airborne turret to compute the wave front distortions of a beam propagating from the turret. The ultimate goal of the research is to maintain laser effectiveness. Optical distortions result from density variations in the air flow over a turret and in its wake, effectively reducing the laser effectiveness. Using reduced-order modeling, the research has shown that the surface pressure around the window can be used to predict the optical aberrations and thus reduce the effect of the disturbances by more than 50 percent.

The MSRC is not limited to CFD work only, and the Department of Chemistry remains an active partner. As part of its basic research study, and with the help of the MSRC, the cadets and faculty of the Chemistry Department have initiated an exciting and new collaboration in biochemical molecular modeling with AFRL and the Defense Threat reduction Agency. The modeling centers on identifying and selecting peptides and DNA aptimers for study as explosives, illicit drugs and/or chem-bio agents sensors. The benefits of a multi-agent sensor can help not only our Air Force warfighters, but also DoD and other law enforcement and government agencies. In addition, the Chemistry Department is integrating computational and molecular modeling into their curriculum to give their chemistry majors cutting-edge modeling skills.

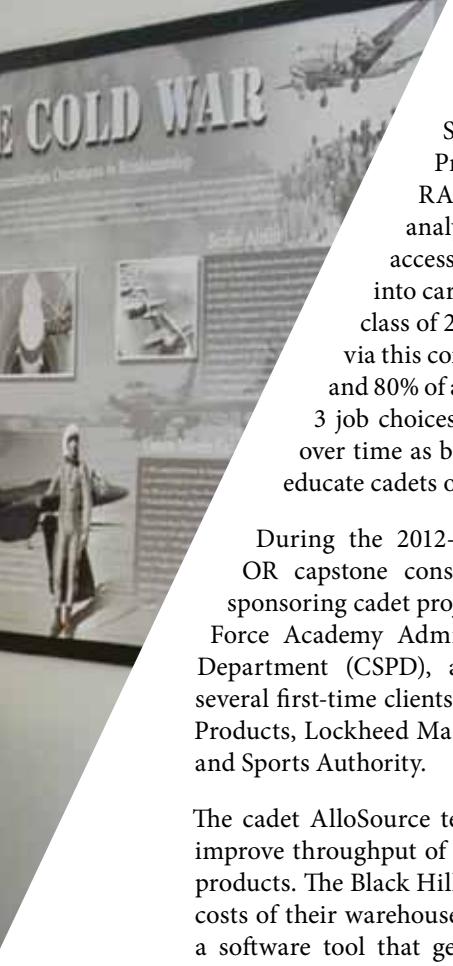
"Computing technology will continue to get faster," said Lt Col Lofthouse, "and the MSRC will be here to harness its use."

OPERATIONS RESEARCH

To paraphrase the new Dean of the Faculty, Brigadier General Andrew Armacost, operations research "lives in the seams" of many other disciplines' research efforts. Operations research has also become a dynamic force throughout USAFA research and includes contributions from the Departments of Computer Science, Management, Economics and Geosciences, and Mathematical Sciences.

Operations Research (OR) professionals "provide insight" within their research and consultations. Thus, providing insight is the theme of the OR Capstone Experience. Over the past year, OR faculty and cadets teamed to improve the operations of several organizations.

"Cadets have amazing, innovative ideas. They are not constrained by the old adage, 'We've always done it that way!' The Academy's OR Capstone allows these ideas to be tested with analytical techniques based on mathematics and statistics, while leveraging computer programming to create a user-friendly interface. But the job isn't done until the client understands the solution and is convinced of the proposed benefits," said Lt Col Tim Pettit of the Academy's Department of Management "That's where management and economics play an important role in OR—estimation of costs and rewards are the goal for each Capstone project. Leaving the Academy with practical experience working with real clients, on real problems provides them a solid foundation to begin active duty in the Air Force."



Supporting the Air Force Accession Process, OR faculty worked with RAND and AF Personnel Center analysts to develop a single model to access both Academy and ROTC cadets into career fields (AFSCs). The graduating class of 2013 was the first to receive AFSCs via this combined model: 92% of AFA cadets and 80% of all cadets receiving one of their top 3 job choices. Accession metrics will improve over time as both accession sources continue to educate cadets of their "best fit" opportunities.

During the 2012-2013 AY, cadets participated in OR capstone consultations with 15 organizations sponsoring cadet projects. Perennial clients such as Air Force Academy Admissions, Colorado Springs Police Department (CSPD), and Allosource were joined by several first-time clients such as Black Hills Energy, RMB Products, Lockheed Martin, FedEx, Northgate Properties and Sports Authority.

The cadet AlloSource team created a scheduling tool to improve throughput of valuable bone and tissue medical products. The Black Hills Energy team reduced inventory costs of their warehouse in Pueblo, Colorado by creating a software tool that generates recommended inventory levels and reorder points given a desired level of service. A cadet team analyzed coupon distribution for Denver-based Sports Authority and recommended changes to coupon distribution to increase profits. Working with incentaHEALTH's Weigh-and-Win initiative, cadets sought to improve retention by identifying the best educational material and incentives based on participant characteristics. Their findings allow the Weigh-and-Win initiative to better focus resources while ultimately improving participants' health.

In another example, cadet teams worked with Lockheed Martin. One project involved designing products for a "Flightline of the Future." The cadets created an optimization that located structures in order to minimize movement and thus increase aircraft availability. The outputs of the optimization can be viewed in Google Earth, providing a quick, worldwide visualization of the optimal base layout.

While clients, faculty and cadets all benefit from the consultations, each year the cadets also receive external accolades. Several teams excelled at West Point's Donald R. Keith Cadet Capstone Conference against students from West Point, Columbia University, George Mason University, the University of Texas, the University of Arkansas, and Youngstown State University. The Flightline of the Future cadet team competed against West Point at Lockheed Martin's Center for Innovation and took first place in the modeling category. Additionally, several cadet teams presented at the annual Colorado Springs Undergraduate Research Forum.

SCHOLARSHIP OF TEACHING AND LEARNING

It's been another stellar year for the Scholarship of Teaching and Learning (SoTL) at the United States Air Force Academy. Over the course of the 2012/2013 AY, faculty from across all academic disciplines actively engaged in research projects, discussion groups, and participation at the annual SoTL Forum.

During the September 2012 SoTL, Forum 25 research projects were showcased, participants participated in panel sessions, and they listened to Dr. John Medina, author of *Brain Rules* as the keynote speaker for a standing-room-only opening session. Enthusiasm for exploring how to apply brain science to enhance cadet learning spilled over into the full academic year as more than 40 faculty members regularly met in small groups to discuss chapters in *Brain Rules*. "The desire to enhance learning went well beyond the discussion stage, however," stated Dr. Lauren Scharff, Director of the Scholarship of Teaching and Learning Program. "New and continuing projects have continued to make a positive impact on cadet learning and engagement across the Academy."

Carrying on from the spring of 2012, Capt Hanna Yang (Department of Law) further developed the use of interjected feedback comments in video recordings of cadet oral presentations. The use of interjected comments, similar to captions across the bottom of the video image, is a novel approach allowing "spot on" targeting of feedback, similar to interjected written feedback comments that are typically placed within papers. Capt Yang's project was nominated for a competitive award at the 24th International Conference on College Teaching and Learning.

Also advancing an effort to incorporate technology to enhance learning, Dr. Thomas Phelan and Capt Joseph Sundy from the Department of Civil and Environmental Engineering investigated the use of electronic video tutorials to provide additional assistance to cadets at night and on weekends when faculty typically aren't available. These videos focused on the more challenging topics, such as static forces on submerged surfaces and momentum forces. Feedback from students suggests that cadets regularly viewed and want more such video tutorials.

In the Department of Foreign Languages (DFF), a new series of projects led by Distinguished Visiting Professor, Dr. Sheri Long, Department Head Col Daniel Uribe, Lt Col LeAnn Derby, and SoTL Director, Dr. Lauren Scharff kicked off during the Fall 2012 semester with an exploration of the current status of leadership development within the department's courses. This exploration of the Foreign Language Department's leadership development connects with its mission statement, "To develop leaders of character with global perspective through world-class language and culture education," and with directives from the American Council on the Teaching of Foreign Languages to incorporate "leadership and responsibility" into foreign language classrooms. Results showed many generic and implicit examples of leadership incorporation, but very few explicit, discipline-specific examples, although cadets and faculty both expressed a strong interest to have more discipline-specific activities. Three follow-on efforts during the Spring 2013 semester explored ways to advance leadership development within the foreign languages context. C2C Jasmine Leyro and C2C David Heaphy led a project allowing them to use their training in research methods to investigate how syllabus design and different ways inclusion of the department's mission statement within the syllabus impacted student retention of syllabus information and attitudes toward foreign language courses. Dr. Long and Dr. James Rasmussen employed reflective journals and joint German-Spanish discussion sessions to document student perceptions of what leadership looks like across cultures and assess whether and how those perceptions change during the semester. Finally, over 20 faculty members, representing all eight languages within the department, regularly met as part of a faculty learning community, exploring and sharing ideas about ways to use real-life cultural scenarios, panels of international visitors, and multi-language exchanges to more explicitly implement intentional and integrated leadership development in foreign language instruction and learning.

Another highlight of the 2012–2013 AY was the awarding of the first Martinson SoTL research award at the annual USAFA Research Awards Ceremony, where top researchers from across USAFA were recognized. This new award recognizes outstanding research in the area of

the Scholarship of Teaching and Learning, with criteria including evidence of positive impact on cadet learning both within and beyond the involved courses, overall excellence of the research, and acceptance of the research by experts in the field. This year we received seven outstanding nominations from across the Academy, illustrating the pervasive passion to enhance cadet learning at USAFA: Dr. Michelle Butler, (Department of Behavioral Sciences and Leadership), Dr. Ismenia De Souza, (Department of Foreign Languages), Major Timothy Frank, (Department of Civil Engineering), Dr. Sarah Robinson, (Department of Economics and Geosciences), Dr. James Rolf, (formerly of the Department of Mathematics and Statistics), Dr. Steve Spicklemire, (Distinguished Visiting Professor in the Department of Physics), and Capt Hanna Yang (Department of Law). Although the decision was tough, we were pleased to announce that the first recipient was Major Frank. His work included two major projects, the first of which involved the use of learning contracts in several DFCE courses, and the second investigating the impact of a new interdisciplinary course in Foreign Area Studies. As a follow-on to the interdisciplinary course, Major Frank and some of his students visited Mozambique over spring break this year to begin implementation of the water purification method they designed for that population and their environmental constraints.

"It is inspiring," said Scharff. "The SoTL work at USAFA not only impacts cadet learning in our courses, but also has far-reaching impact, both over time and beyond our Academy."

SPACE PHYSICS AND ATMOSPHERIC RESEARCH CENTER

The mission of the Space Physics and Atmospheric Research Center (SPARC) is to provide cadets real-world research experience, allowing them to "learn space by doing space."

Led by Dr. Geoff McHarg, SPARC's goal is to develop the next generation of space professionals via one-on-one research with cadets in areas of interest to the Department of Defense. Cadets learn about the space environment and how that environment affects people and man-made systems with hands-on, real-world opportunities. Cadets design, build, calibrate, and operate DoD or Air Force funded sensors and eventually analyze data using a variety of methods that probe the space environment using in situ and remote sensing techniques.

Dr. McHarg commented on the contributions by the cadets to SPARC success. "We have cadets from three different departments working with us this year. This broad range of skills has been critical to our research efforts. Successful teams in the Air Force capitalize on the diverse capabilities of their members, and our cadets are bringing their best efforts ever." The Miniaturized Electrostatic Analyzer (MESA) and Canary instruments onboard the International Space Station (ISS), along with the micro-gravity test of the Peregrine deployable telescope are some of the recent SPARC success stories.

The cadet-designed and built MESA has flown on several spacecraft and provided measurements of ionospheric density, temperature, and satellite charging. The most recent MESA mission was part of the Materials International Space Station

Experiment number 7 (MISSE-7) flown to the International Space Station (ISS) in November 2009 and returned to Earth on STS-134 in June 2011. This MESA experiment was operated by cadets and faculty at the Air Force Academy using a remote ground station capability provided by the National Aeronautics and Space Administration (NASA). The MESA instrument was developed and delivered by cadets from previous classes.

In 2012–2013, C1Cs Brandon Mueller, Lance Wilhelm and Zachary Hoeffner used data from MESA as the basis for their physics capstone project. Cadets Mueller and Wilhelm presented their results at the Space Test Program Data Exchange in Washington D.C. and at the SEASONS conference sponsored by Johns Hopkins University during the fall semester of 2012. Cadet Hoeffner continued this analysis and is comparing the results from MESA with an instrument on the ISS run by NASA.

A dozen SPARC cadets took part in the highly successful Canary project during the 2012–2013 academic year. Canary is an ion spectrometer designed to measure the interaction of rocket plumes from arriving spacecraft with the ISS. Canary was built in partnership with the Johns Hopkins University Applied Physics Laboratory and was delivered to the ISS by STS-134. Canary continues to operate without error on the ISS. This spring SPARC faculty and cadets collected data for a continuous 72 hours during a period when the ISS was flying "backwards," thus pointing Canary into the ionosphere. This unusual orientation will afford faculty and cadets the chance to calibrate the Canary measurements of the rocket plumes it normally gathers with the well-known signature obtained from observing the ionosphere. During this entire time period the NASA Floating Potential Measurement Unit (FPMU) was operating as well, giving researchers another chance to cross calibrate the Canary data. Working directly with NASA space professionals, Canary is a great example of how cadets "learn space by doing space."

In 2012-13, SPARC cadets performed a micro-gravity experiment on the deployment system of the Peregrine solar telescope. Peregrine is designed to take images of the Sun using a deployable space telescope. A multi-disciplinary project involving several USAFA Research Centers, Peregrine uses membrane optics technology developed in collaboration with the Laser and Optics Research Center (LORC). Peregrine is the payload on FalconSAT-7 (FS-7), a small "CubeSat" satellite. Cadet Heather Nelson and Lt (former Cadet) Samantha Latch were responsible for operationally testing the telescope, getting a unique opportunity to experience the low-gravity environment of NASA's infamous "vomit comet." Cadet Nelson summarized her experience, "It was a once in a lifetime opportunity that I've always dreamed of and it was a priceless test environment for our system—definitely a win-win!"

The FS-7 and Peregrine payload is funded by the Defense Advanced Research Projects Agency (DARPA) and is built in collaboration with students at the Air Force Institute of Technology at Wright-Patterson AFB, AFRL professionals at Kirtland AFB, and scientists at NASA's Goddard Space Flight Center. This project will see the first ever space flight of a membrane telescope and is slated for delivery to a launch provider in 2015.

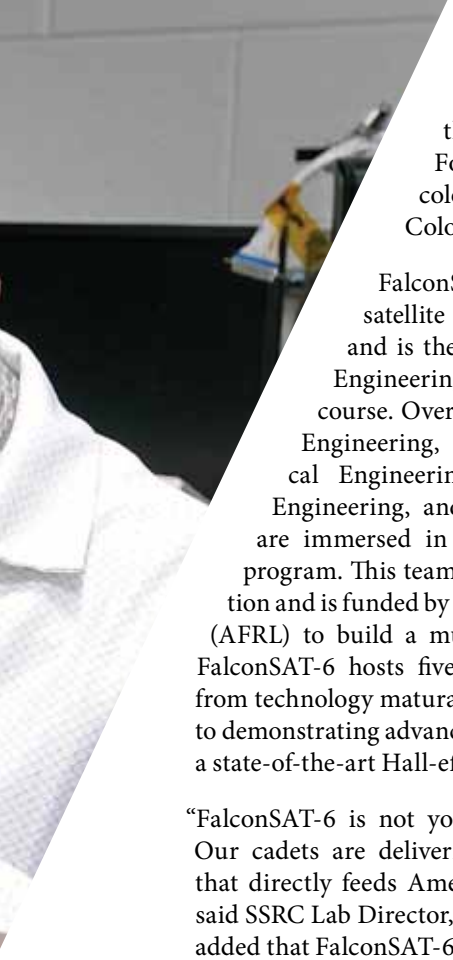
SPARC continues to be successful in performing its mission to develop the next generation of space professionals by providing cadets the opportunity to research real projects of interest to the DoD. SPARC faculty and cadets are becoming known as a hotbed of novel science missions for the Air Force. SPARC is supporting the overall Air Force Academy mission to educate, train, and inspire men and women to become officers of character, motivated to lead the United States Air Force in service to our nation.

SPACE SYSTEMS RESEARCH CENTER

"Learning Space by Doing Space" is not only the motto of the Space Systems Research Center (SSRC), it is a way of life. Within the SSRC, FalconSAT is the flagship cadet-built small satellite program, unparalleled in the world at the undergraduate level. The SSRC also hosts the USAFA Propulsion Laboratory, the FalconOPS ground station, and provides direct support to nearly all courses within the Department of Astronautics at the USAF Academy. All SSRC activities are guided by one primary goal: to support USAFA in our endeavor to educate, train, and inspire cadets to fly, fight, and win in air, space, and cyberspace, with a clear focus on space. As our Air Force shifts it focus from a century of success in aviation to new frontiers in space and cyberspace, the SSRC will do our part to prepare cadets for this new world.

The FalconSAT program is in its 17th year, preceded by a decade of learning with high altitude balloons and experiments aboard the Space Shuttle. FalconSAT-3 is in its sixth year of on-orbit operations, resulting in thousands of satellite contacts from our FalconOPS ground station. Operations crews, inspired by operational space professionals from Schriever AFB, are composed of cadet teams of all class years, mentored by faculty within the SSRC.

"More than 600 cadets and many visitors have taken part in operating real Air Force space vehicles like FalconSAT-3 and FalconSAT-5. They all played a key role in advancing space technology and adding a unique and valuable experience



that followed them into their Air Force journeys," said retired USAF colonel and SSRC faculty member Colonel Jack Anthony.

FalconSAT-6 is the latest cadet-built satellite program under development and is the centerpiece of the Astronautical Engineering undergraduate degree capstone course. Over 30 cadets from the Astronautical Engineering, Electrical Engineering, Mechanical Engineering, Computer Science, Systems Engineering, and Management degree programs are immersed in a "real world" interdisciplinary program. This team functions as contractor organization and is funded by the Air Force Research Laboratory (AFRL) to build a multi-million dollar small satellite. FalconSAT-6 hosts five distinct payloads, which range from technology maturation of next-generation solar cells to demonstrating advanced maneuvering capabilities from a state-of-the-art Hall-effect thruster.

"FalconSAT-6 is not your typical senior design project. Our cadets are delivering a technology demonstration that directly feeds America's space programs of record," said SSRC Lab Director, Lt Col David Barnhart. Barnhart added that FalconSAT-6 will ride on STP-2 in 2015, which is the Space Test Program's second purpose-built mission, hosted on a SpaceX Falcon Heavy.

FalconSAT-6 also benefits from partnership with NASA's Johnson Space Center (JSC) in Houston TX. The Electronic Systems Test laboratory at JSC is providing their Apollo-era and Shuttle proven 16-foot S-band antenna to support the FalconSAT-6 mission. STP-2 will deliver FalconSAT-6 to a 720 Km, 24-degree inclined orbit, which results in limited access from USAFA, with an average of three passes a day for a total of 20 minutes of contact time. With JSC's ground station in support, that number of passes per day increases to six and the access time is increased four-fold.

Although FalconSAT has been the mainstay program for years, the SSRC is continually innovating and exploring new cadet experiences. Lt Gen Hyten, the Vice Commander of Air Force Space Command, attended the December 2012 SSRC programs end of semester review. Gen Hyten complimented and challenged SSRC cadets, saying, "You are doing spectacular things. Unlike previous generations of space warfighters, your generation will actually have to fight through the emerging contested environment in space."

The SSRC is a true learning laboratory for the Department of Astronautics. Beyond the capstone course, SSRC is developing new learning-focused experiences and technologies for most of the courses in our degree program. Developments such as the EyasSat Educational Satellite System, which was spun off as a commercial company selling over 300 units to date, have made an impact not only

to USAFA, but to the active Air Force as a part of the Space 100 and 200 professional space cadre development courses.

Lt Ken Moak, a 2012 graduate, summarized the SSRC program best: "I have found that I'm probably the most technically-oriented student in my [Intel Officer Training] class. Months of FalconSAT research, as well as countless discussions with my Astro instructors and mentors, have provided me with a unique knowledge and skill set. I have a strong suspicion that I'll be the go-to guy for any questions my classmates may have about all things space-related. When I initially began working on FalconSAT, I felt the program might change my career path. Now, my experiences in FalconSAT are driving base selections on my first assignment dream sheet. Thank you for allowing FalconSAT to shape my last year at USAFA and, quite possibly, my entire career."

FUNDING STATUS FOR RESEARCH AT USAF ACADEMY

Research at the United States Air Force Academy (USAFA) continues to be a highlight of the cadet experience and promotes an environment enabling cadets' critical thinking and analytical skills, as well as shaping their future job prospects. In the classroom and in the laboratory, cadets learn important negotiation and relationship skills required of future officers. Moreover, as in recent years, when funding impacts a cadet's ability to conduct research, he or she quickly absorbs a broader perspective from which a stronger character and "business savy" is manifest. As Dr. Jim Solti, the USAFA Deputy Director of Research, puts it "While sequestration offers a myriad of challenges, one positive externality has been in compelling us to think outside-the-box and explore alternate opportunities which would have otherwise gone unrealized and which will undoubtedly benefit our program and personnel in the years to come."

Despite a decrease in financial support from year's passed, the Academy research program continues to flourish. Recently the National Science Foundation (NSF) reported ranks (from FY12) of universities across the country, and USAFA is the number one undergraduate-only institution for research expenditures in the country for the fourth straight year. The future looks bright for USAFA research with two new organizations materializing in recent months; the Department of Behavioral Science and Leadership's Warfighter Effectiveness Research Center (WERC) and the multi-disciplinary Energy Research Working Group (ERG). Colonel Robert Kraus, Chief Scientist, describes the benefits of the ERG, "We gathered

the diverse groups of faculty conducting energy research so we can leverage the work that each group is doing and cadets reap a multitude of opportunities." The USAFA research program currently has nineteen research centers and two institutes that collaborate with research partners to contribute to the education, training, and inspiration of cadets.

The USAFA Office of Research assists with the appropriate agreement to make partnerships come to fruition. Cooperative Research and Development Agreements (CRADA) are used for partnering with non-federal entities. Whether it is for a cadet's senior capstone course or an intriguing independent study in their field of interest, these agreements allow every cadet the opportunity for exposure to an array of research projects. USAFA's participation in other types of collaborations truly diversifies the cadet experience. This includes Service Academy competitions like Boeing's "Aircraft of the Future" and Lockheed-Martin's "Flightline of the Future." One cadet took this multi-academy competition and fueled his CSRP, led his design team capstone, and was awarded a PhD fellowship to Purdue University!

Each year, for almost 200 cadets, the "research experience" is underscored by a Summer Research opportunity, occurring between the junior and senior year. The experience is often referenced as a highlight of a cadet's emerging professional career and truly shapes their understanding of what it means to support the warfighter. Although we saw a decrease in the number of Air Force and DoD sponsors in 2013, we increased other government agency partnerships as well as corporate participants.

The research programs have a total value of $64 million for the 2013 Fiscal Year (FY13). This number is comprised of three categories: External In-Kind, External Funding, and Internal Support (See Figure 1). External In-Kind support includes the value of visiting researchers and supercomputer time contributed by the Department of Defense High Performance Computing Modernization Office, which totaled $8 million. The External In-Kind piece of the research program, now more than ever, is a valuable asset that nearly all departments leverage. These contributions to the USAFA's research program vary from non-federal entities' personnel spending time on site with cadets and faculty to other partners, like AFOSR's National Research Council sponsoring esteemed researchers and professors to work at USAFA for a year. The Internal support value is determined by an evaluation of USAFA-provided laboratory facilities, USAFA personnel time, and totaled $11.3 million. External funding, valued at $44.6 million, is the direct monetary funding that research centers receive from outside partners, pulled in from the Department of Defense (DoD), other government sources and non-federal entities. In the recent year more funds received from government agencies like Department of Homeland Security (DHS) and others have encouraged stabilization of funding. USAFA continues to receive core funding for basic research from the Air Force Office of Scientific Research (AFOSR), the basic research manager of the Air Force Research Laboratory.

The number one focus of research at the Academy is cadet involvement, and the conversation begins with an interest in cadet-centered research opportunities. Phone calls or emails are welcome.

USAFA's Office of Research
Phone: (719) 333-4195
Email: research@usafa.edu

Fig. 1 Econometric Value (FY13)
(in millions)

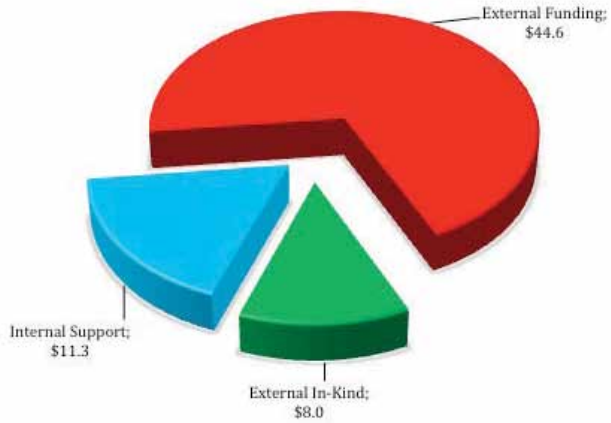


Figure 1 identifies the full spectrum of funding sources for FY13 (as of September 11, 2013). These funds are managed by USAFA's Dean of Faculty Budget Office and the Office of Research.

Fig. 2 External Funding Sources by Fiscal Year (FY)

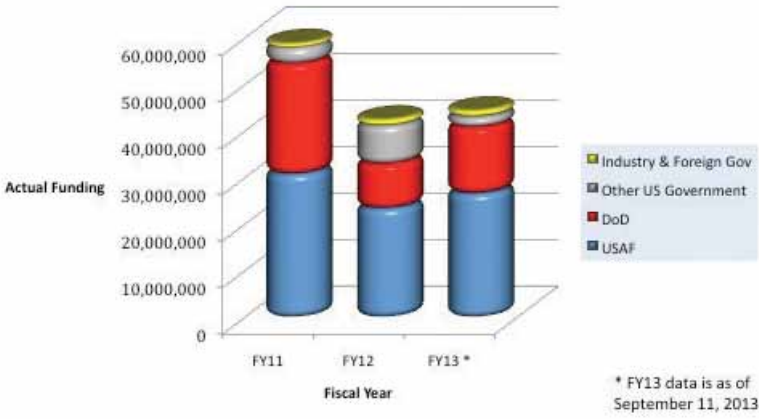


Figure 2 indicates the sources of external funding for research for comparison from FY11 through FY13 (as of September 11, 2013).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SUSTAINED BY THE
POWER OF HIS
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